Appendix K

WATER EXPERIMENT STATION PORT EVERGLADES/ PALM BEACH DREDGED MATERIAL FATE STUDIES

Port Everglades/Palm Beach Dredged Material Fate Studies

Introduction

An evaluation of the Port Everglades and Palm Beach Ocean Dredged Material Disposal Sites (ODMDSs) was accomplished in a previous study (Cialone, M. A. and Lillycrop, L. S., 1998)[1]. However, additional work was requested by the U. S. Army Engineer District, Jacksonville (SAJ) to clarify, justify and further examine the study results.

The Port Everglades ODMDS is located east-northeast of Port Everglades and approximately 8 km offshore (Figure 1). The 3.4 km^2 site is defined by the following corner points:

26° 07' 30"N, 80° 02' 00"W
26° 07' 30"N, 80° 01' 00"W
26° 06' 30"N, 80° 02' 00"W
26° 06' 30"N, 80° 01' 00"W

The site is centered at 26° 07' 00"N, 80° 01' 00"W. The ODMDS is located on the upper continental shelf with depths ranging from 176 to 217 m (Figure 2).

The Palm Beach ODMDS is located east-northeast of Lake Worth Inlet and approximately 8 km offshore (Figure 3). The 3.4 km^2 site is defined by the following corner points:

26° 47' 30"N, 79° 57' 09"W
26° 47' 30"N, 79° 56' 02"W
26° 46' 30"N, 79° 56' 02"W
26° 46' 30"N, 79° 57' 09"W

The site is centered at 26° 47' 00"N, 79° 56' 33"W. The ODMDS is located on the

---

[1] Cialone, M. A., Lillycrop, L. S. (1998). "Dispersion Characteristics for Palm Beach and Port Everglades Ocean Dredged Material Disposal Sites (ODMDSs)" (Unpublished Miscellaneous Paper).

upper continental slope with depths ranging from 155 to 185 m (Figure 4).
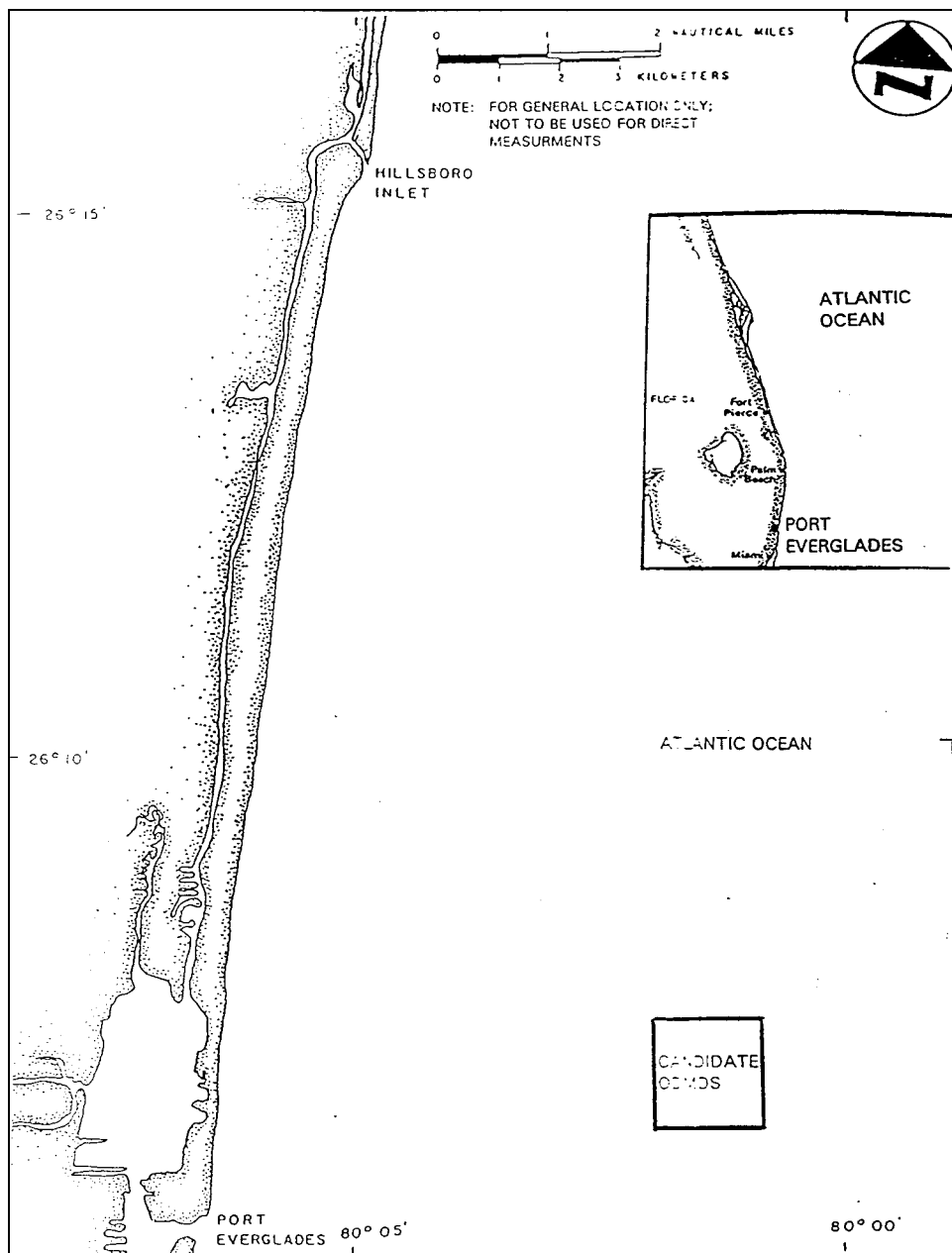

Figure 1. Location map of the Proposed ODMDS, Port Everglades, FL
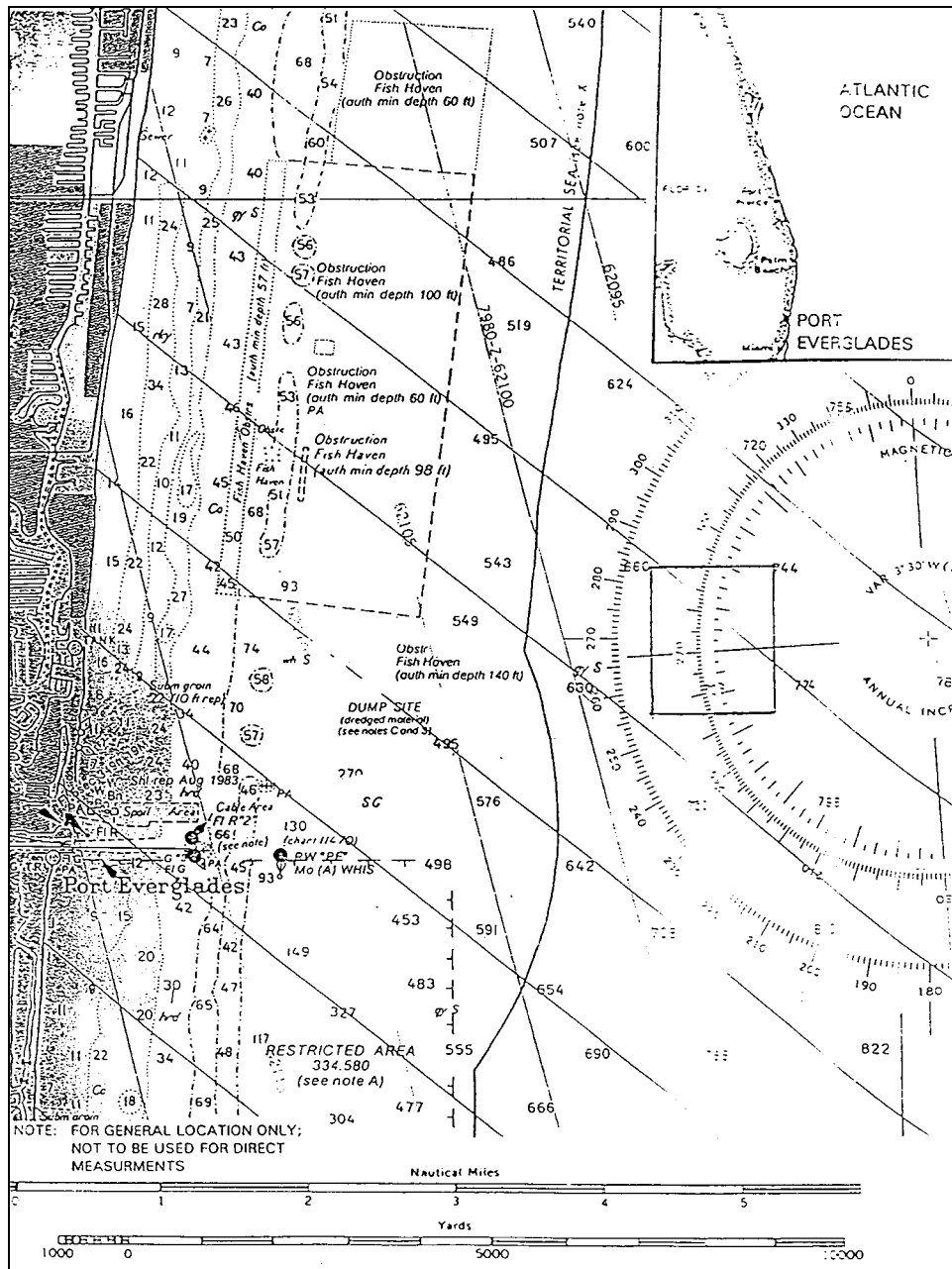(from Continental Shelf Associates, Inc. 1989)

Figure 2. Bathymetry in the vicinity of the proposed Port Everglades ODMDS (from NOAA, 1989)
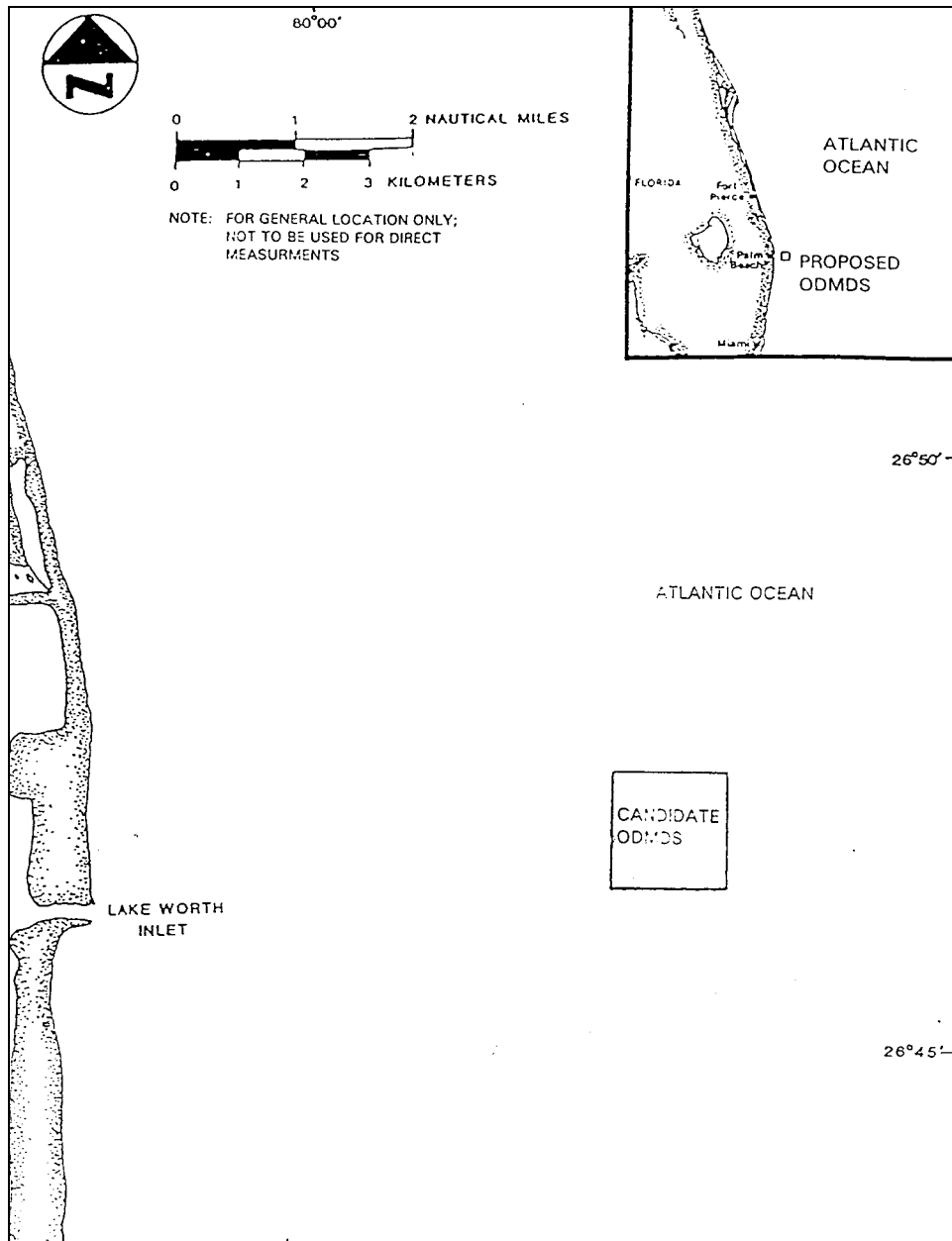
Figure 3. Location map of the proposed ODMDS, Palm Beach, FL
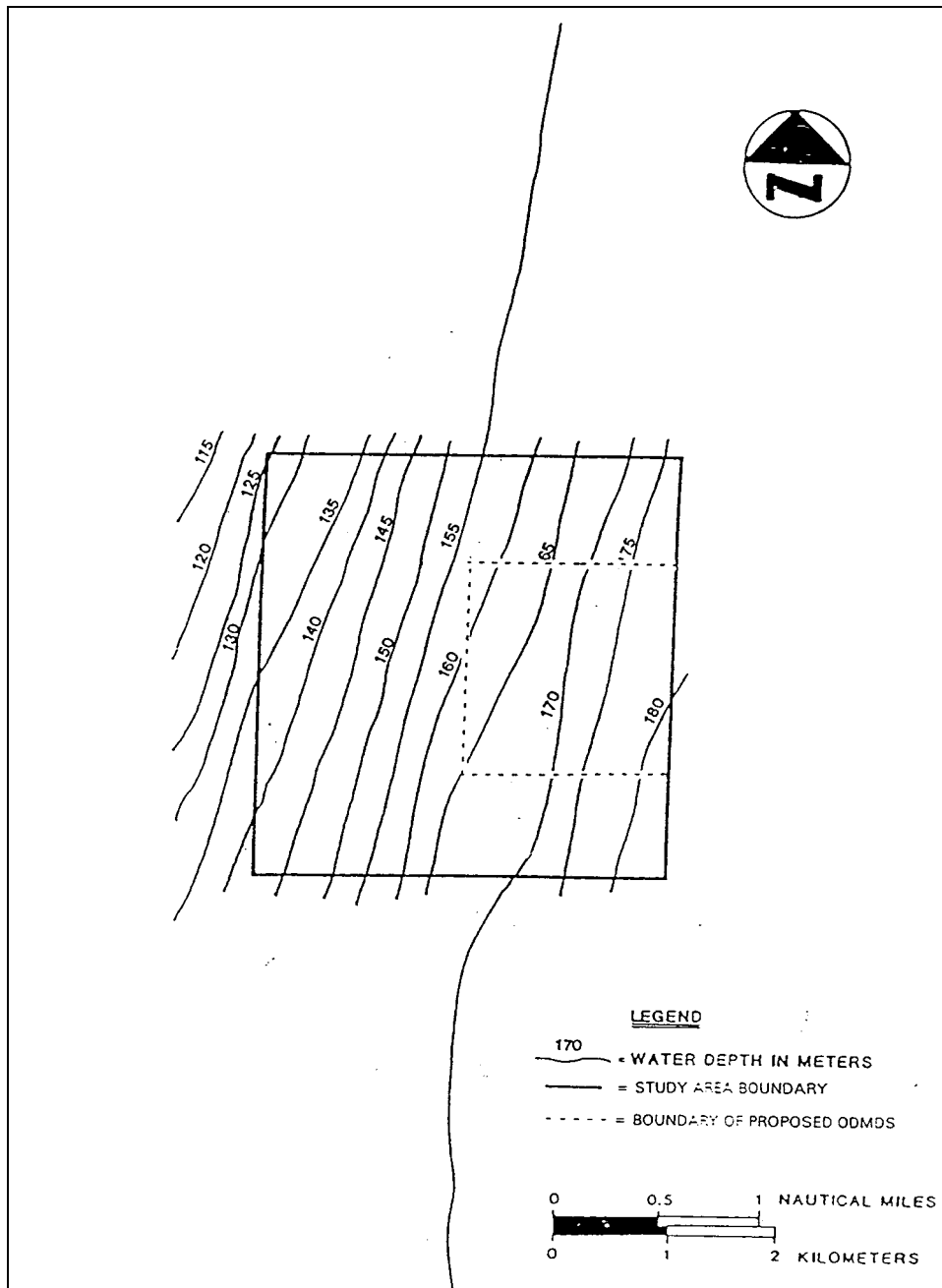(from Continental Shelf Associates, Inc., 1989)

Figure 4. Bathymetry in the vicinity of the proposed Palm Beach ODMDS
(from Continental Shelf Associates, Inc., 1989)

　　　Acoustic Doppler Current Profiler (ADCP) data obtained from the National
Oceanographic Data Center (NODC) for location (26° 04.00'N, 80° 03.50'W)
in the vicinity of the project sites were analyzed to determine potential velocity
profiles that disposed material might be subjected to. The depth at the ADCP
deployment site was 110 m. NODC provided velocity profile data at 4-m depth
intervals and 20-minute time intervals for the 1995-1997 time period.

The purpose of the previous study was to evaluate the dispersive characteristics of proposed disposal sites offshore of Palm Beach Harbor and Port Everglades Harbor. Both disposal sites are in deep water (approximately 170-200 m deep) and are in close proximity to the Gulf Stream and its spin-off eddies. There is concern that the proposed eddies could potentially carry material from the ODMDS to environmentally-sensitive coral reefs. Numerical model simulations were selected as the method of evaluating the potential for sediment transport during disposal and from the disposal mound.

This present study consisted of four main tasks to carry out the additional work requested by SAJ. Task 1 consisted of a) rescaling sediment concentration Short-Term Fate (STFATE) plots to show the entire plume decay in the direction of the reef and b) changing to total sediment concentration plots rather than separate sand and silt-clay concentrations. STFATE model results were available and retrievable for the Port Everglades site. For the Palm Beach site, in some cases data were not retrievable and assumptions were made and are stated in this report.

Task 2 consisted of searching for additional velocity data near Palm Beach and preparing a brief description of the Florida Current. The purpose of this task is to determine if the velocity data are representative of conditions at the Palm Beach ODMDS and justify the use of the ADCP data, which is about 70 km south of the Palm Beach ODMDS, as the velocity input for the Palm Beach site.

Task 3 consisted of STFATE modeling of a typical current profile to provide a description of the disposal event under "typical" current conditions at the ODMDS. The STFATE model was modified to adopt a four-point velocity profile.

Task 4 consisted of the application of a screening-level fate model to estimate the long-term response of the dredged material mound for more conservative volumes. The previous study evaluated the sediment movement of a 50,000 c. y. mound which represents the annual amount that each disposal site is expected to accommodate. The present study evaluates the sediment movement from mounds having larger volumes (500,000 c. y.). The screening level erosion modeling was completed for the three most energetic storms for both sites. An additional case of a severe extratropical storm was simulated for the Port Everglades site.

Where possible, results from the previous study were used or recreated as a basis for the additional work. However, all model results from the previous study were not retrievable and it was not feasible to recreate all the simulations. In these cases, assumptions were made and are stated in this report.

Total Concentration Plots

SAJ requested STFATE plots showing combined sand and silt-clay concentrations. The original plots were prepared to show the concentrations of sand and silt-clay

separately. The model computes the time-history of a single disposal operation from the time the dredged material is released from the barge until it reaches equilibrium. Model simulation data requirements include local water depths, currents, density gradients, disposal description, and sediment characteristics. Model results from the original STFATE simulations for Port Everglades and Palm Beach were retrieved and used to produce total concentration plots.

Port Everglades

Model results from the original STFATE simulations were available and were retrieved. The maximum sand concentration was added to the maximum silt-clay concentration wherever the offshore distance and the alongshore distance coincided. The maximum concentration is the maximum within the grid over the duration of the simulation. For some cases the location of maximum concentrations of sand and silt-clay did not coincide and the calculations were not performed. The total concentrations were calculated at five water depths to describe the variation of the total concentration in the water column. Figures 5-20 show the reconstructed total concentrations versus offshore distances from the reef (grid origin) at each model simulation time step. In all plots westerly-directed and northwesterly-directed velocities are denoted in the figures with a W and N, respectively. Velocities with exceedances of 50% (V_{50}), 10% (V_{90}), 5% (V_{95}), and 1% (V_{99}) were identified in the figures with the designators 50, 90, 95, and 99 respectively. Table 1 shows the depth integrated velocities used in the simulations.

Table 1. Velocities simulated	
Direction and Percentile	Velocity Magnitude (cm/sec)
W50	20
W90	27
W95	40
W99	57
N50	53
N90	128
N95	149
N99	200

Two sediment compositions, 60% and 70% solids by weight, were simulated. Table 2 shows the volume fraction of sand and silt.

Table 2. Port Everglades sediment characteristics			
% solids by weight	% fines	Volume fraction fines	Volume fraction sand
60	38	.1401	.2247
70	5	.0239	.4460

The original model outputs contain maximum concentration values at offshore distances from the reef of no less than 2400 m. This distance is mainly a function of model simulation time, water depth, disposal location and grid boundaries.

In all previously simulated Port Everglades applications sediment was disposed 6100 m from the grid origin (reef location). The sand concentration diminished to a value of 1 mg/l within 3660 m of the reef location and the silt-clay concentrations diminished to approximately 1 mg/l within 4500 m of the reef location (Cialone, M. A. and Lillycrop, L. S., 1998). In the previous study each portion of the sediment was estimated separately and consequently the above-mentioned values represent concentrations at different distances from the reef and for different velocity input conditions.

The present results indicate that under the most severe conditions (N99: 70%), the maximum total sediment concentration within 4000 m from reef location was approximately 3 mg/l at a depth of 137 m. A major portion of the dredged material is sand and the sand concentration was 2.7 mg/l while the silt-clay concentration value was 0.5 mg/l.

The previous and the present studies describe the same model results and the difference in the stated concentration values and their offshore distances is due to the use of calculated total sediment concentration.

Palm Beach

For the Palm Beach site, the only available model results included maximum concentrations of sand and silt-clay, but did not include alongshore locations of the maximum sediment concentration for northwesterly-directed velocities. Therefore, a conservative approach was adopted, for northwesterly-directed velocity cases, by assuming the maximum sand and clay-silt concentrations have the same alongshore distance from the grid origin.
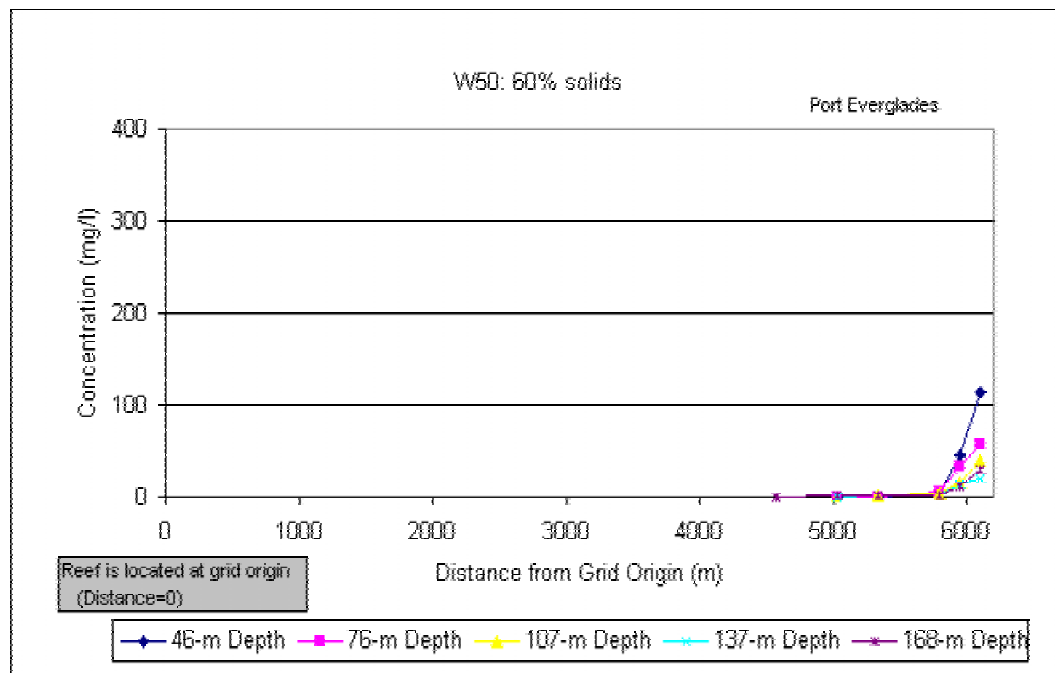
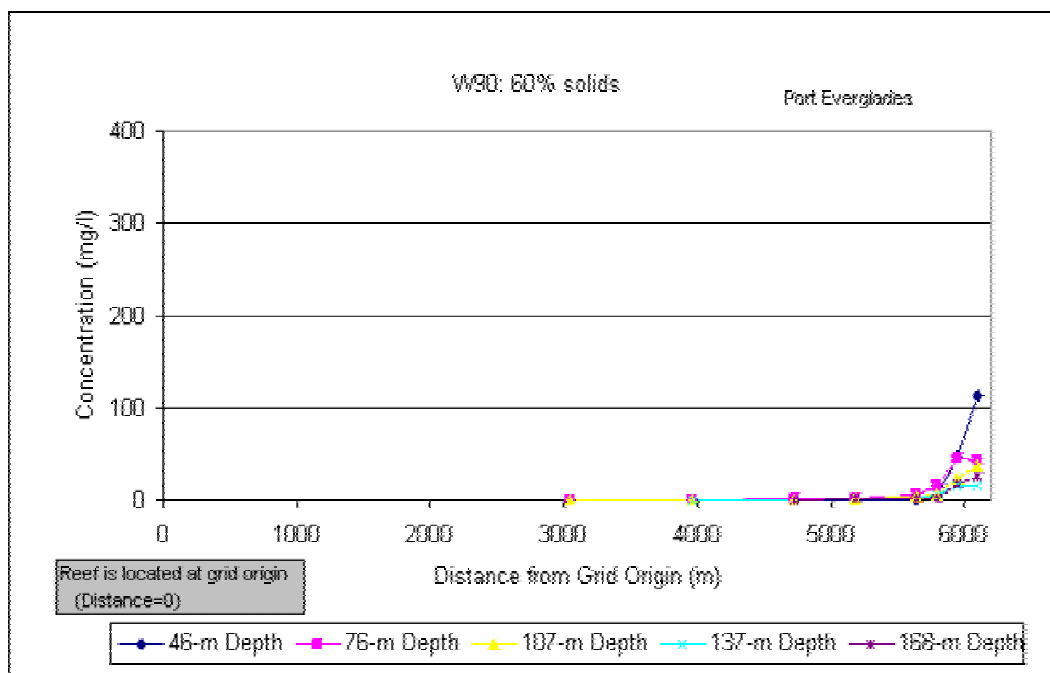Figure 5. Total sediment concentration

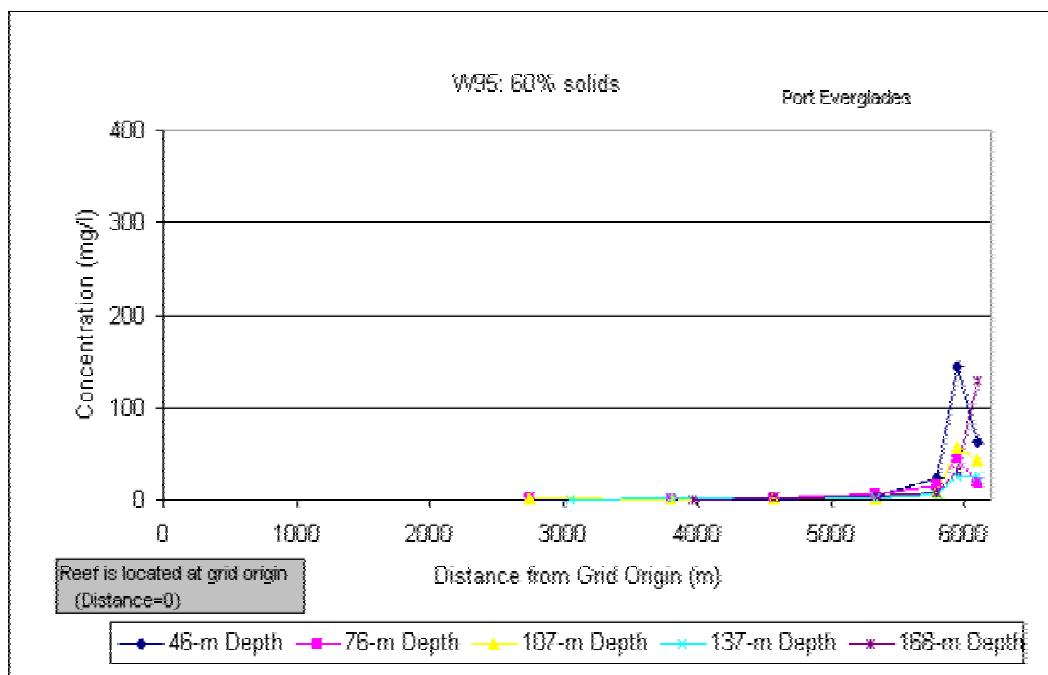

Figure 6. Total sediment concentration
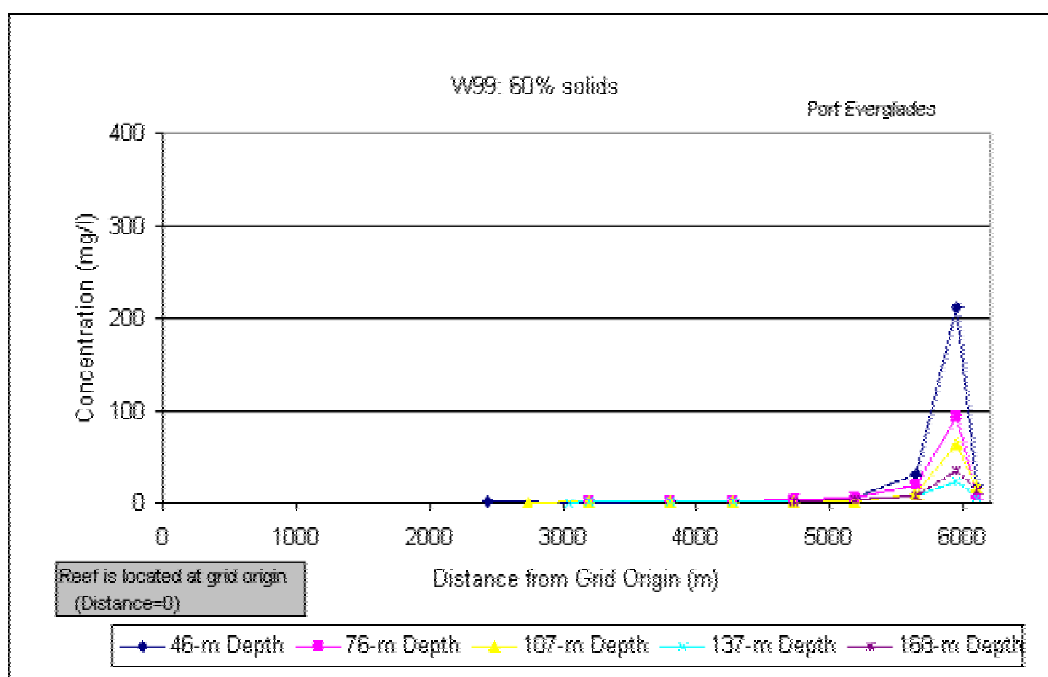
Figure 7. Total sediment concentration

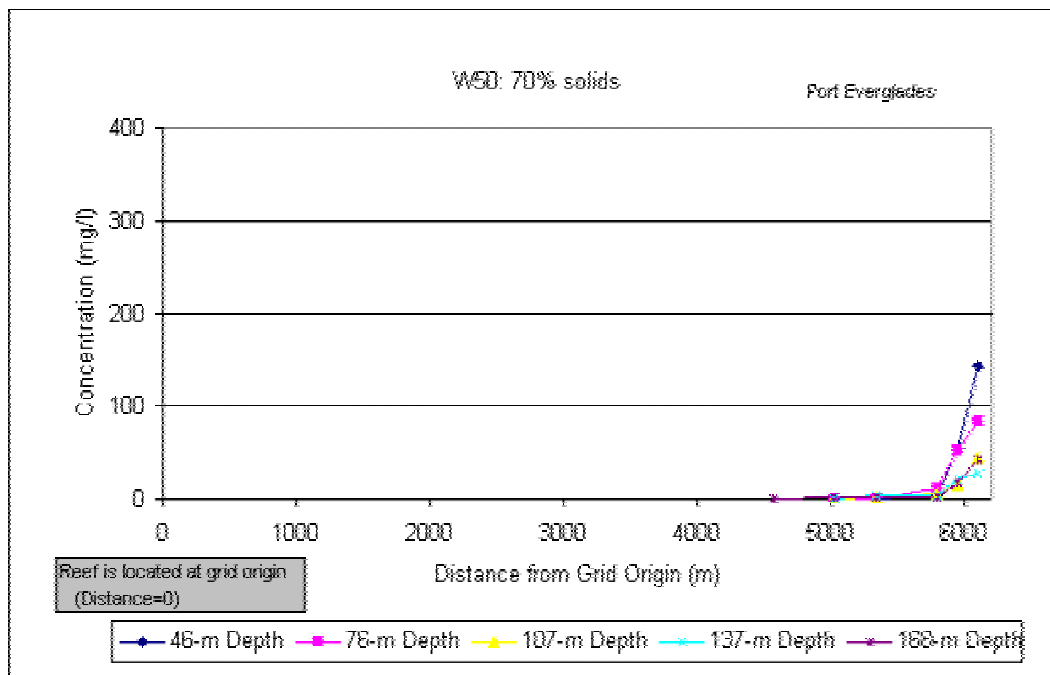Figure 8. Total sediment concentration
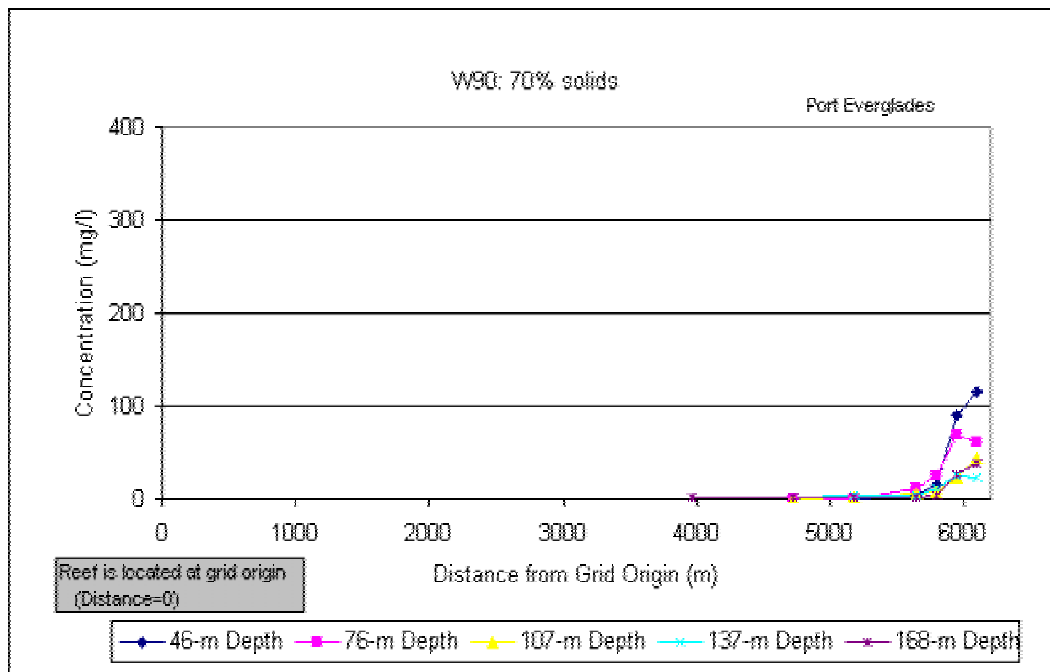
Figure 9. Total sediment concentration
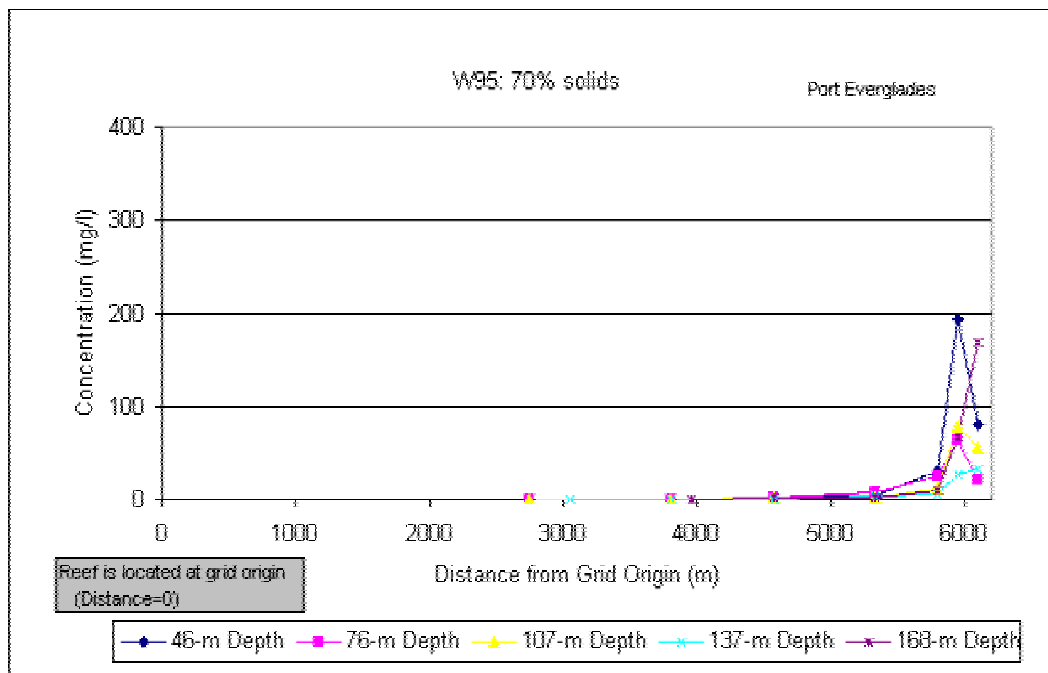

Figure 10. Total sediment concentration
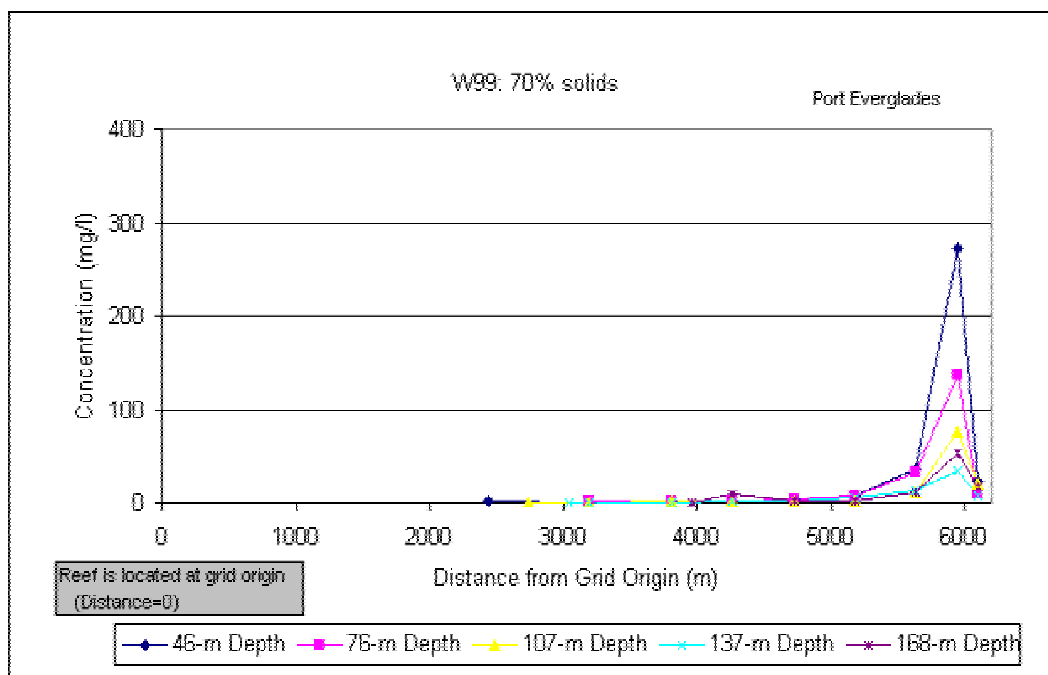
6

Figure 11. Total sediment concentration

Figure 12. Total sediment concentration

Figure 13. Total sediment concentration

Figure 14. Total sediment concentration

Figure 15. Total sediment concentration

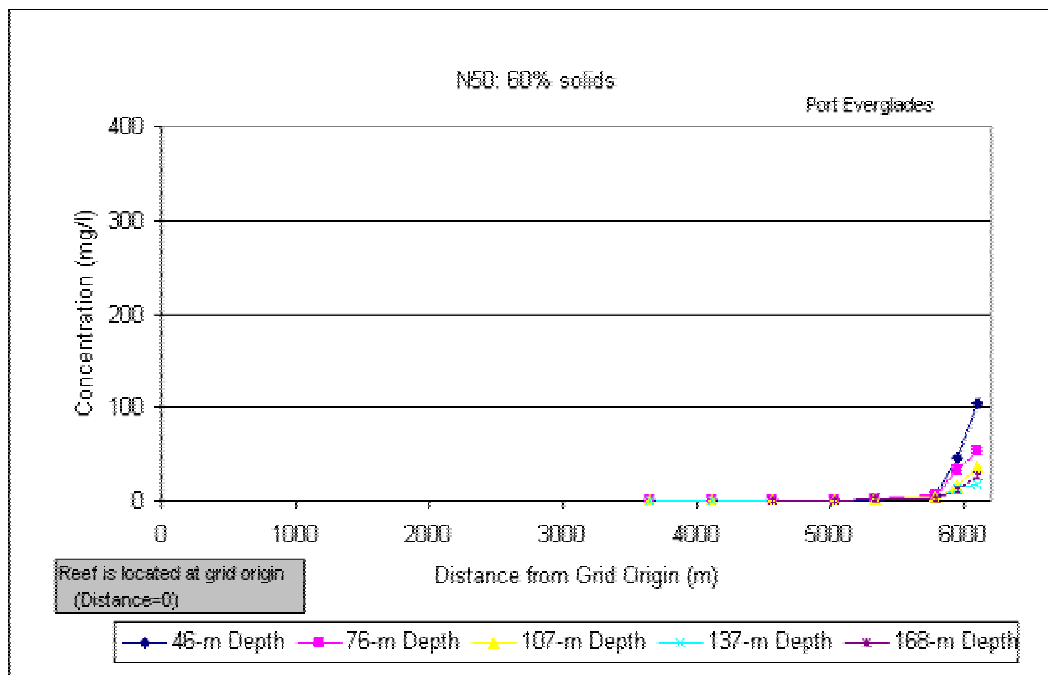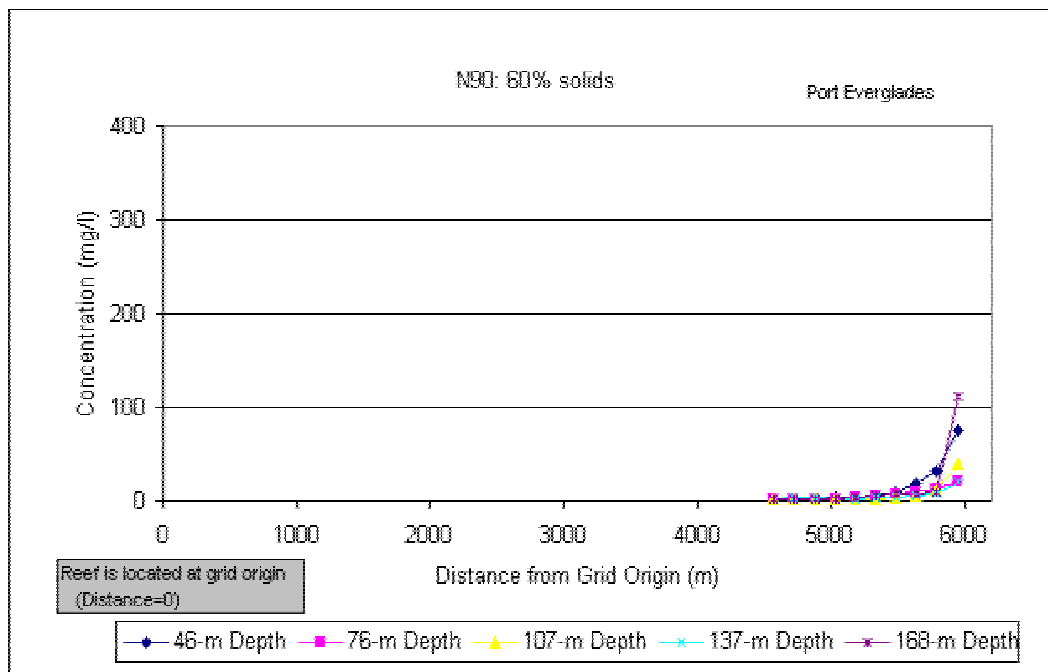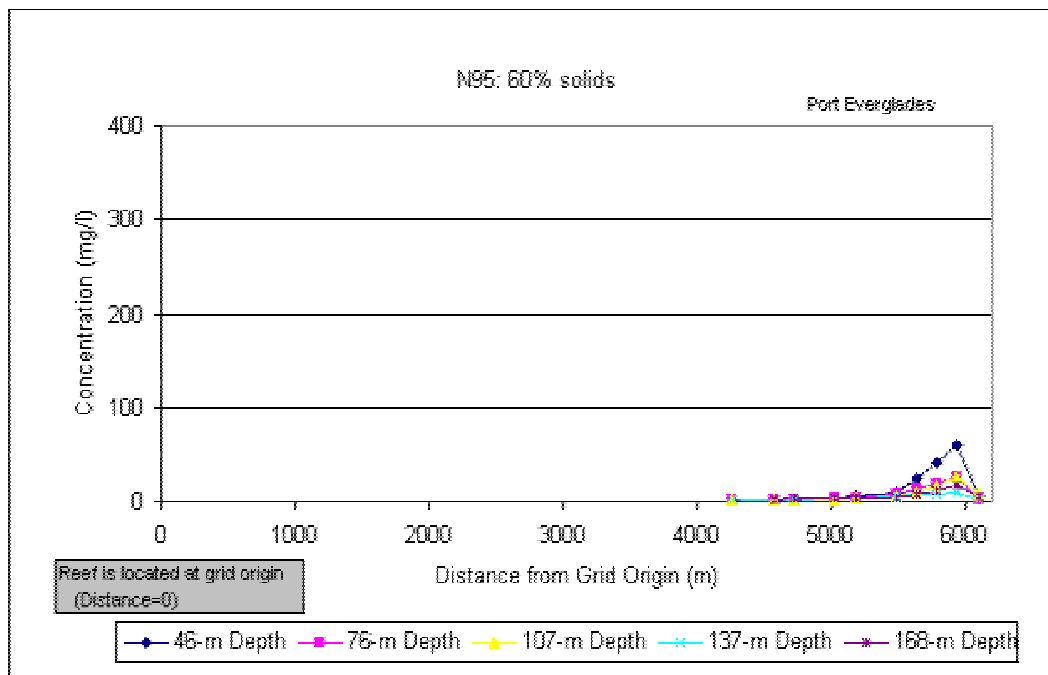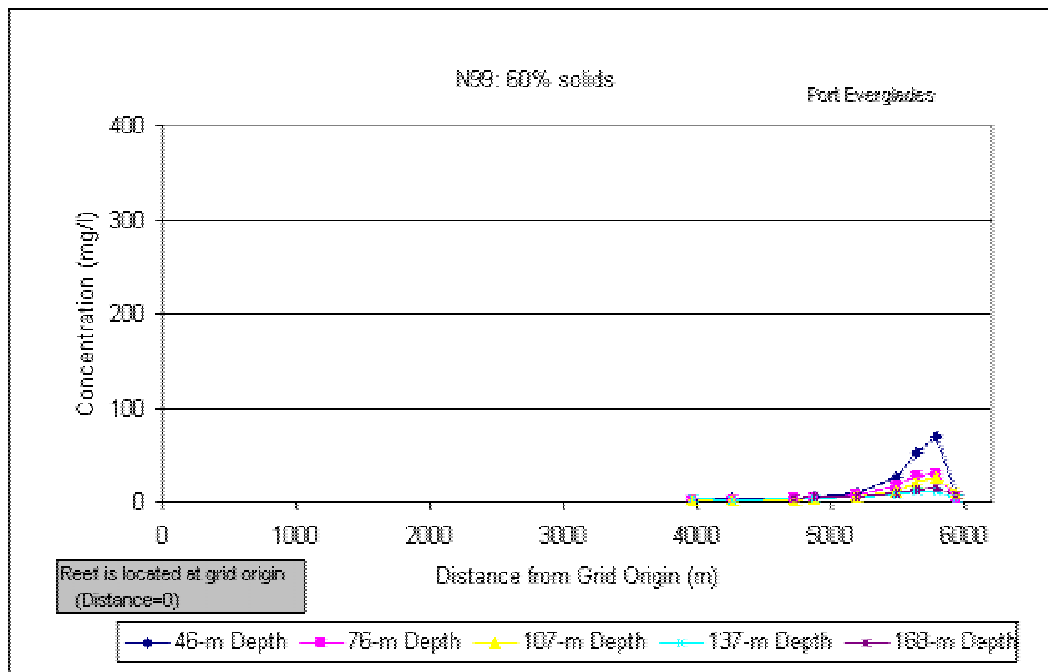Figure 16. Total sediment concentration

Figure 17. Total sediment concentration

Figure 18. Total sediment concentration
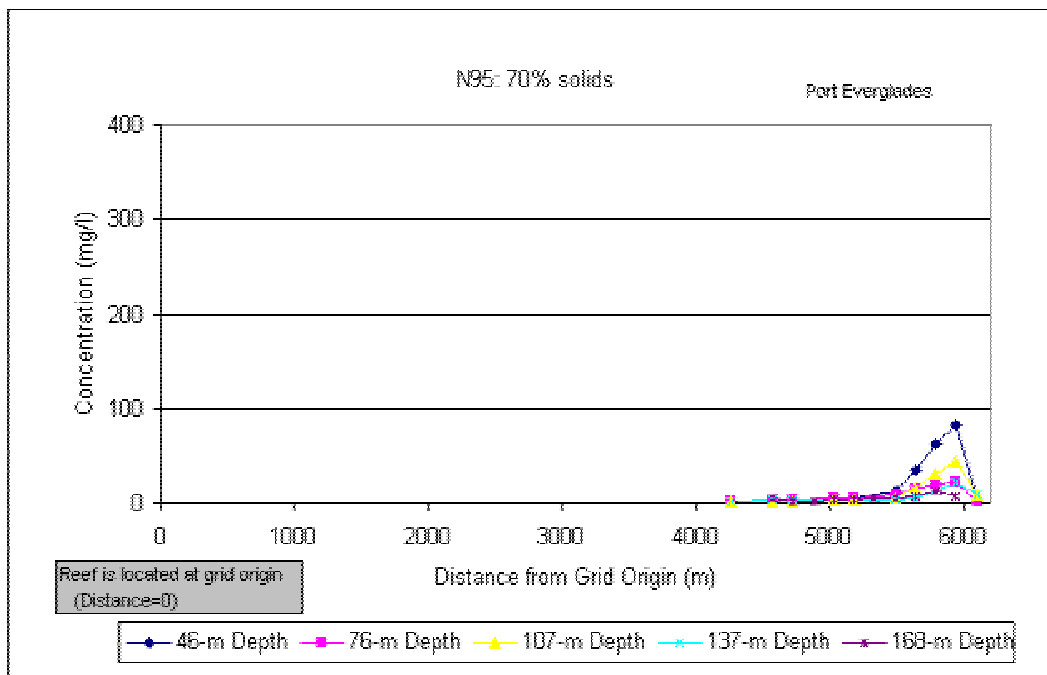
Figure 19. Total sediment concentration

Figure 20. Total sediment concentration

To evaluate the validity of our conservative assumption, the offshore distance and the alongshore distance for all northwesterly-directed velocities at Port Everglades were examined and were found to coincide. It can be inferred from the coincidental locations at Port Everglades that the conservative approach of coincident maximum concentrations adopted

for the northwesterly-directed velocities at Palm Beach can be considered a good assumption. Two sediment compositions were simulated, 80% and 85% solids by weight. Table 3 shows the volume fraction of sand and silt.

Table 3. Palm Beach sediment characteristics

% solids by weight	% fines	Volume fraction fines	Volume fraction sand
80	6	.0368	.5664
85	6	.0417	.6426

The maximum concentration is the maximum within the grid over the duration of the simulation. The total concentrations were calculated at five water depths to describe the variation of the total concentration in the water column. Figures 21-36 show the reconstructed total concentrations versus offshore locations from the reef (grid origin) at each model simulation time step. The original model outputs contain maximum concentration values at offshore distances from the reef of no less than 3600 m. This distance is mainly a function of model simulation time, water depth, disposal location and grid boundaries.

For Palm Beach applications, sediment was disposed approximately 5500 m from the grid origin and not 5300 m as was mentioned in the previous study. The sand concentration diminished to a value of 1 mg/l within 2900 m of the reef location and the silt-clay concentrations diminished to approximately 1 mg/l within 3810 m of the reef location (Cialone, M. A. and Lillycrop, L. S., 1998). In the previous study each portion of the sediment was estimated separately and consequentially the above-mentioned values represent concentrations at different distances from the reef and for different velocity input conditions.

The present results indicate that under the most severe conditions (N99: 85%), the maximum total sediment concentration within 3800 m from reef location was approximately 19 mg/l at a depth of 55 m. A major portion of the dredged material is sand with a concentration of 17.4 mg/l, while the silt-clay concentration value was 1.6 mg/l.

The previous and the present studies describe the same model results and the difference in the stated concentration values and their offshore distances is due to the use of calculated total sediment concentration.

Figure 21. Total sediment concentration

Figure 22. Total sediment concentration

13

Figure 23. Total sediment concentration

Figure 24. Total sediment concentration

Figure 25. Total sediment concentration

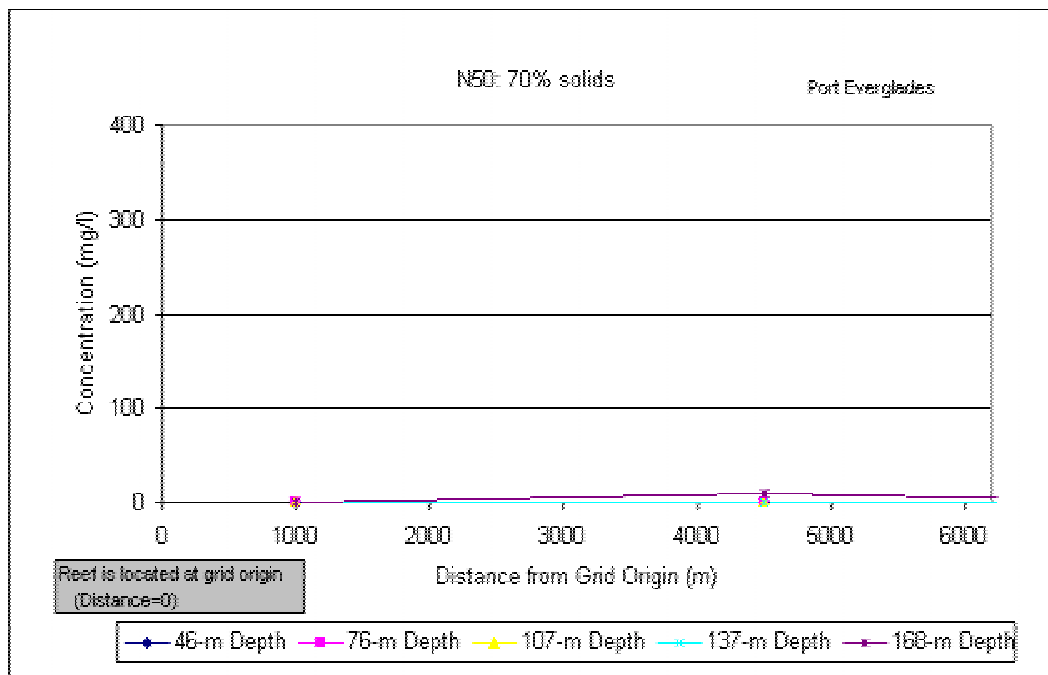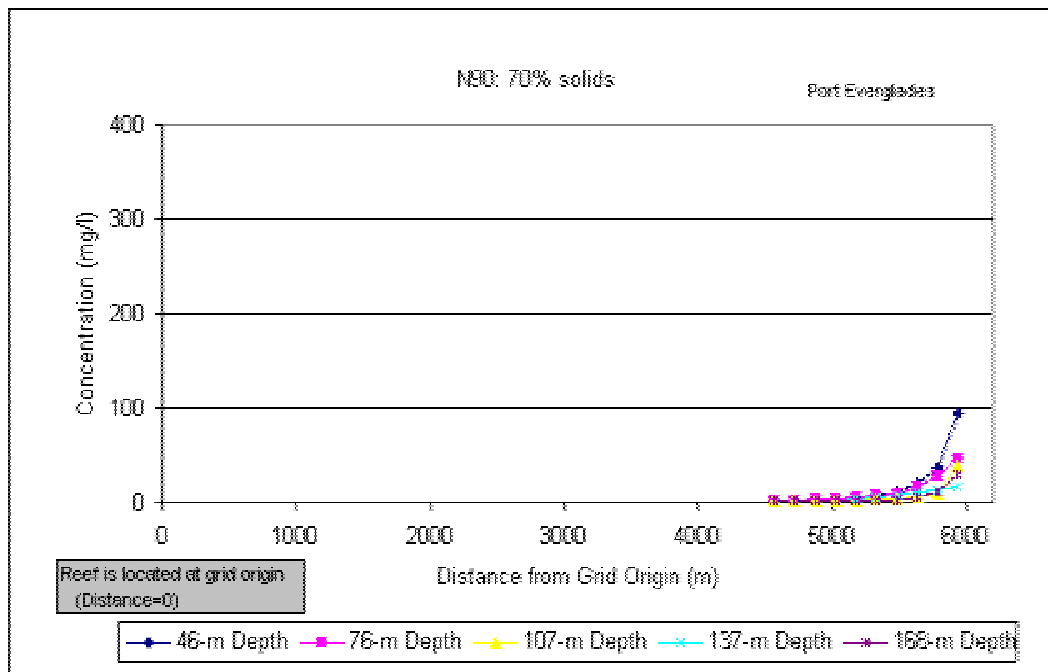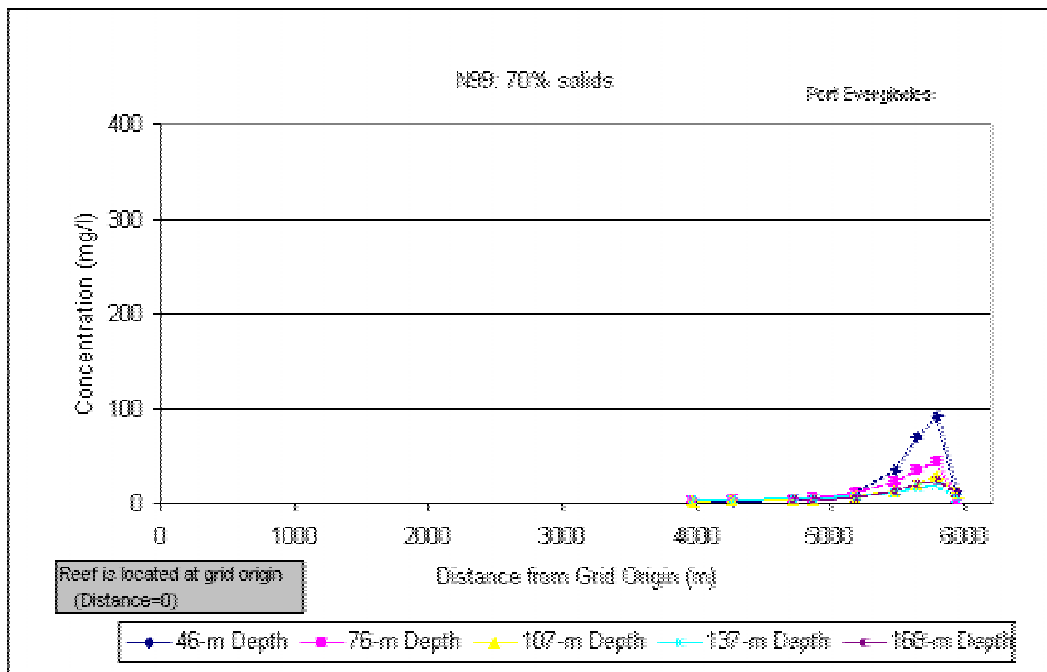Figure 26. Total sediment concentration

Figure 27. Total sediment concentration

Figure 28. Total sediment concentration

Figure 29. Total sediment concentration
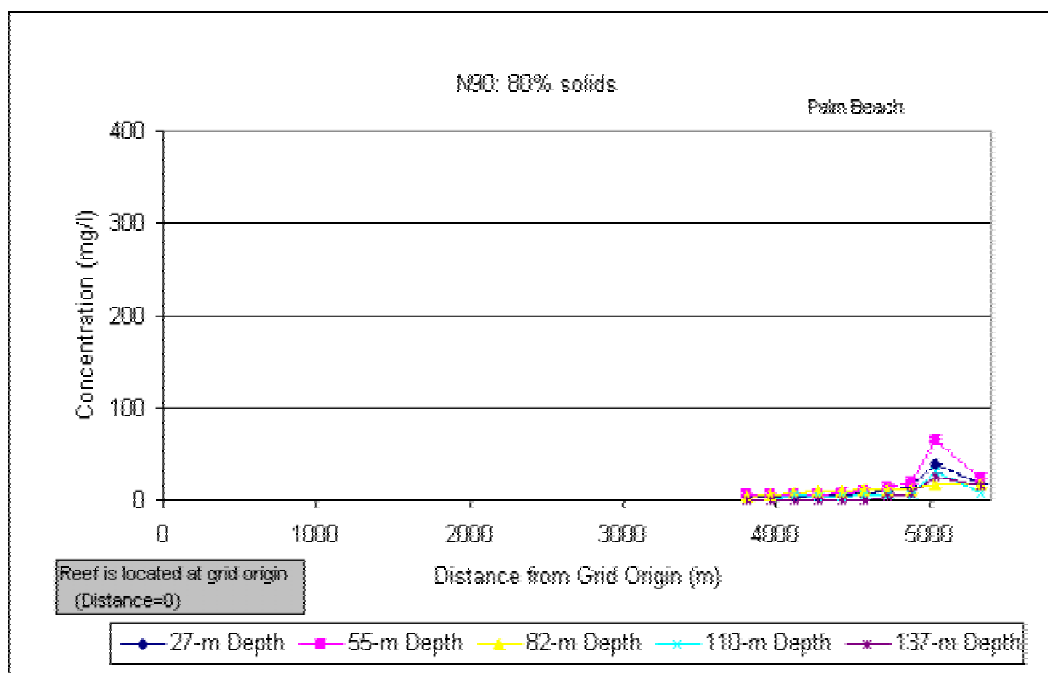
Figure 30. Total sediment concentration
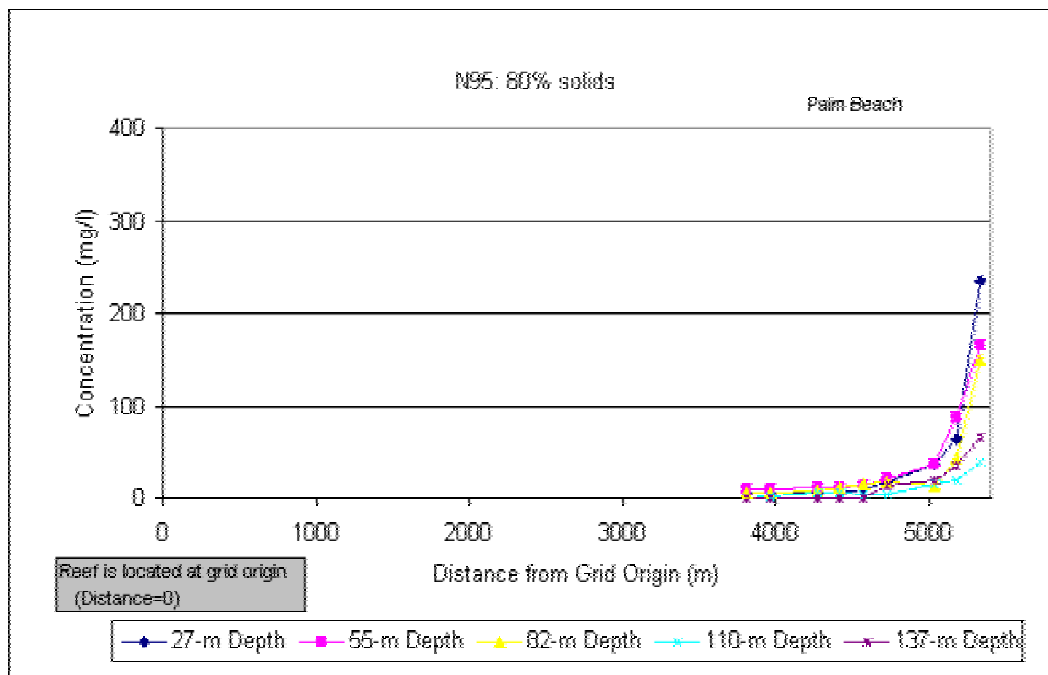
Figure 31. Total sediment concentration
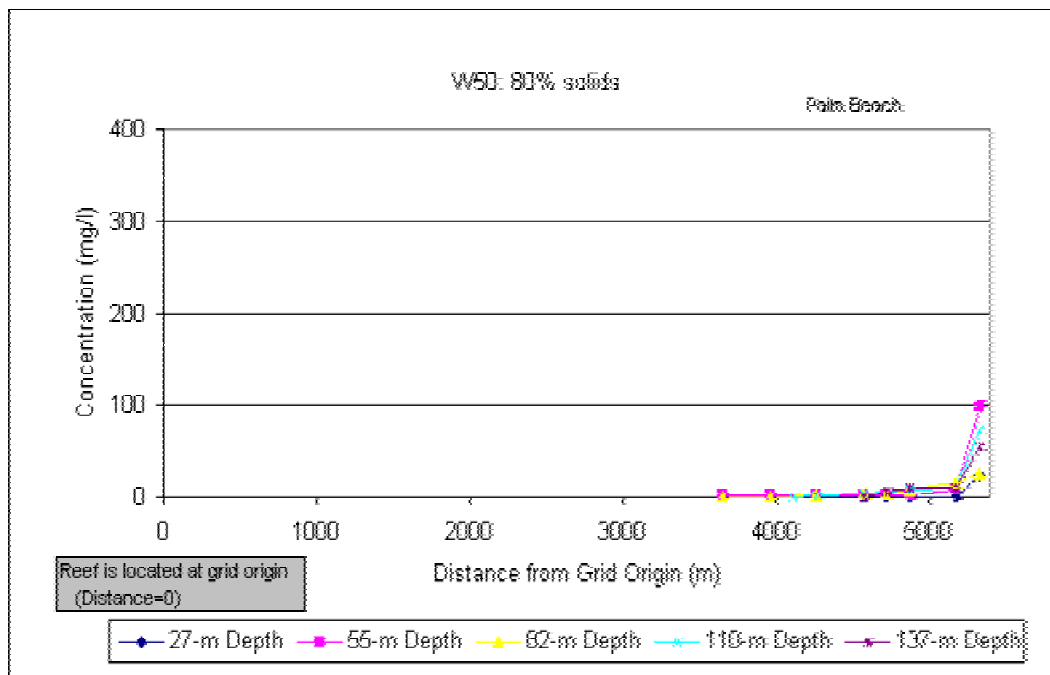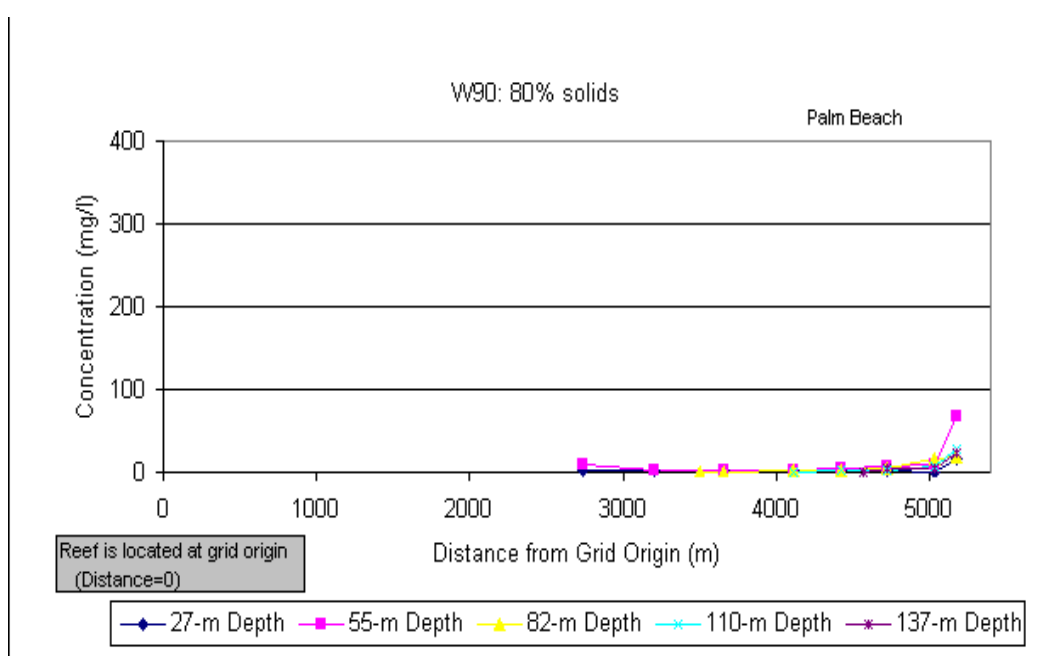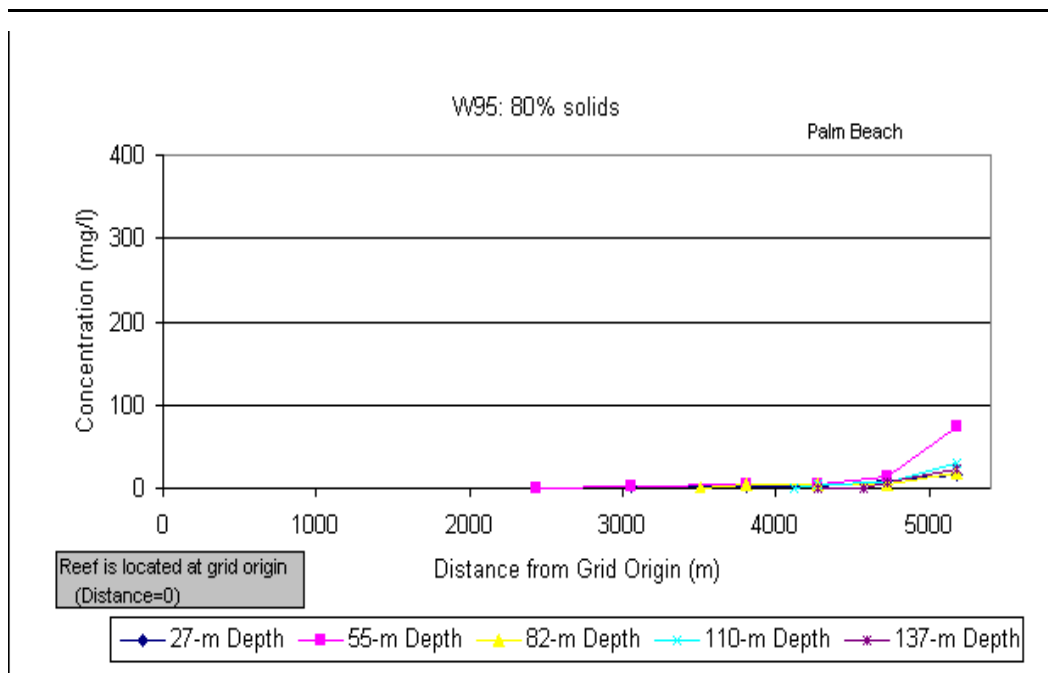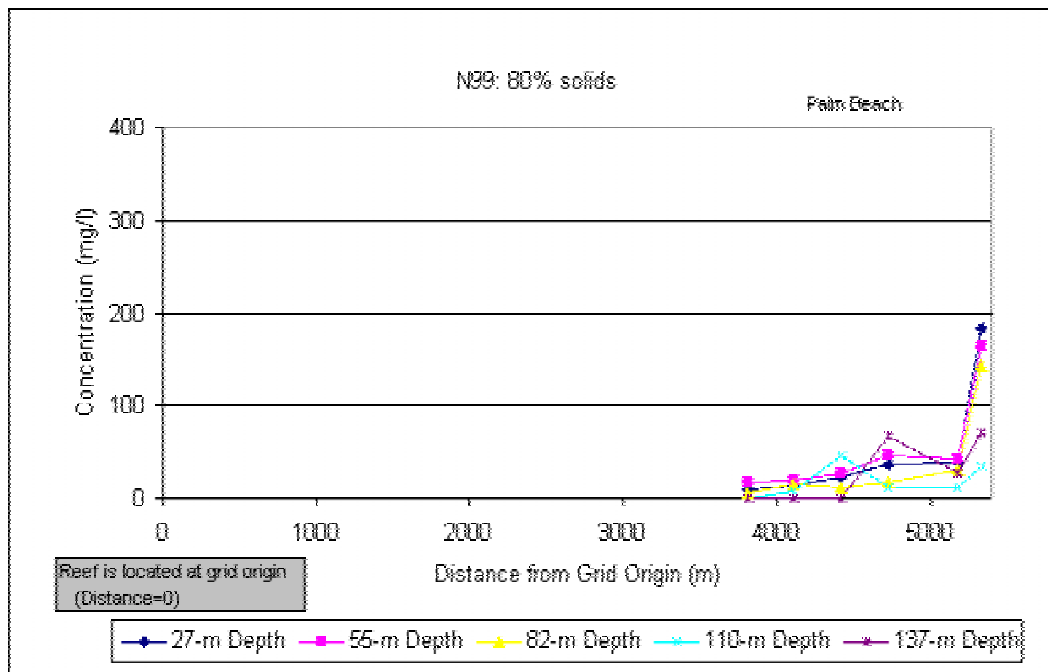

Figure 32. Total sediment concentration

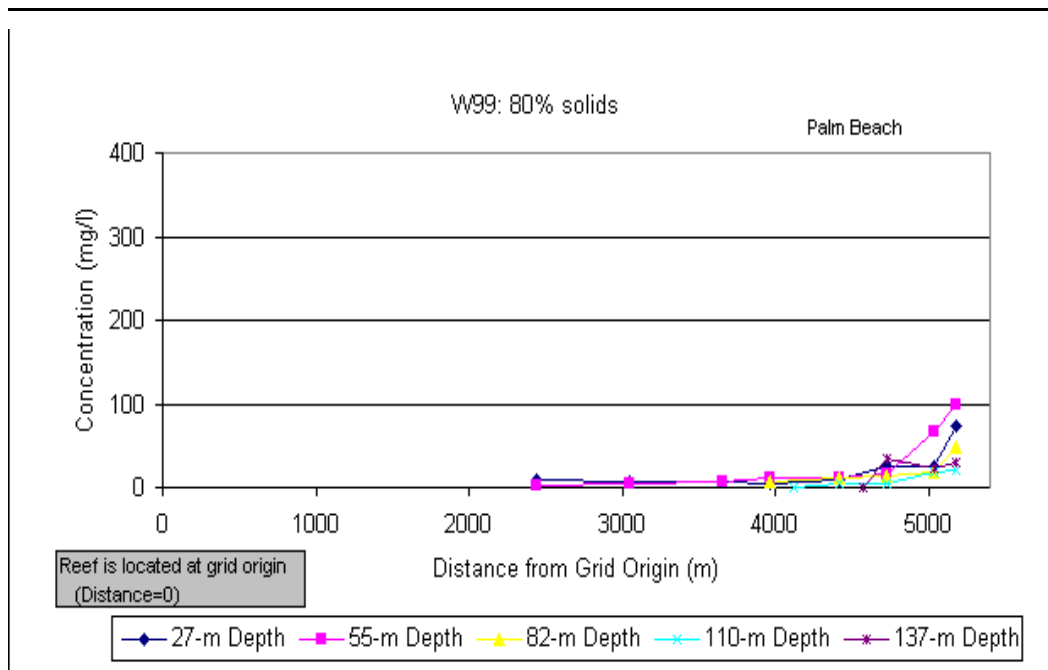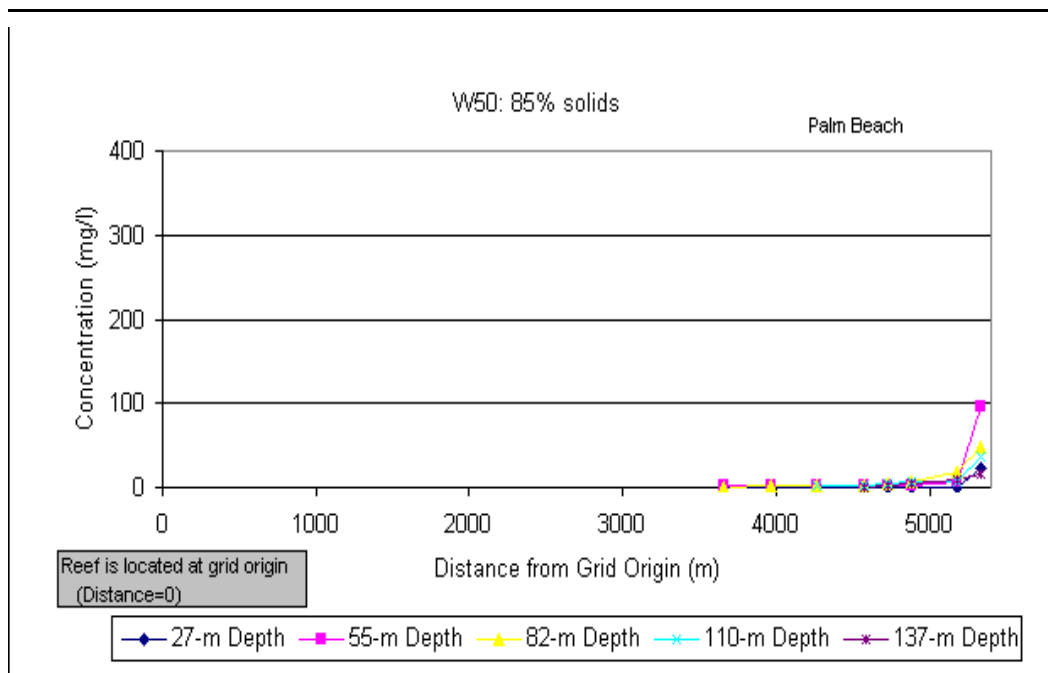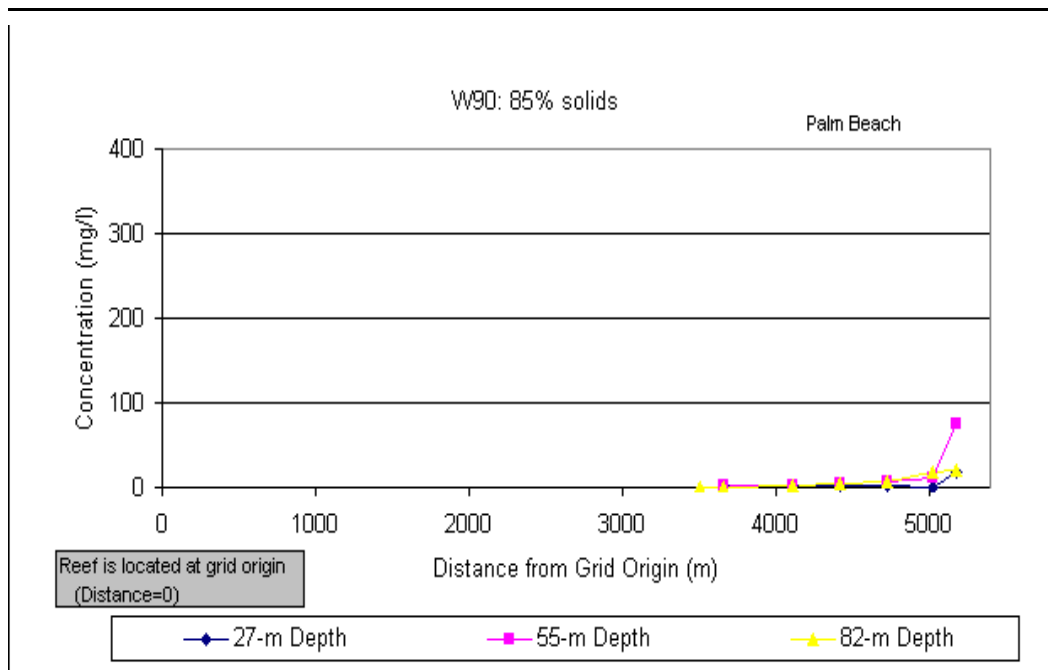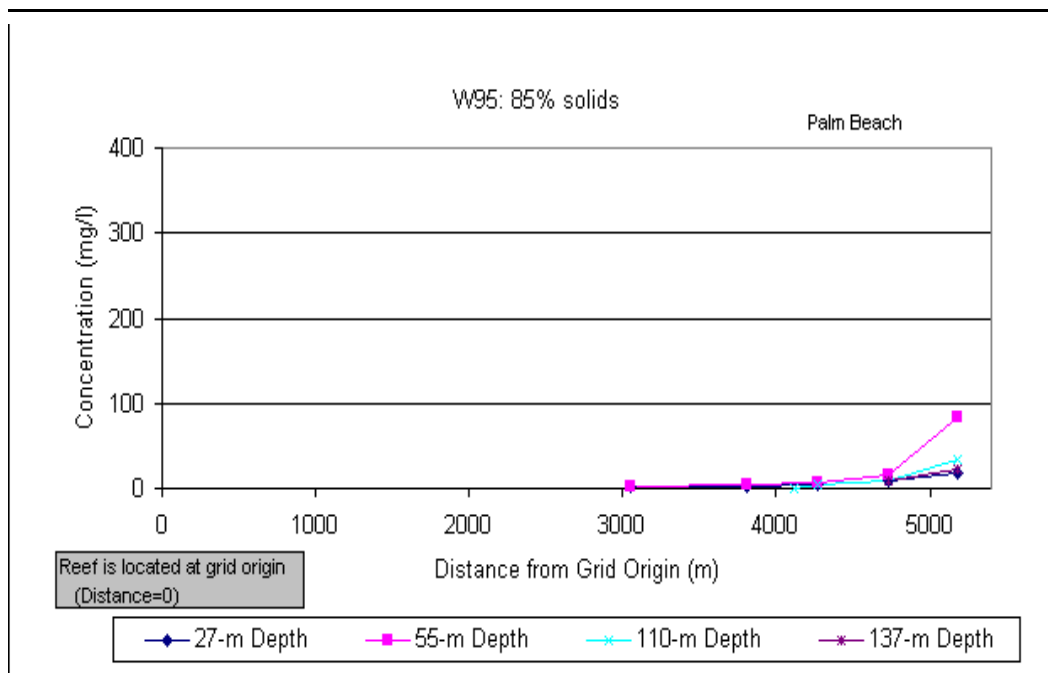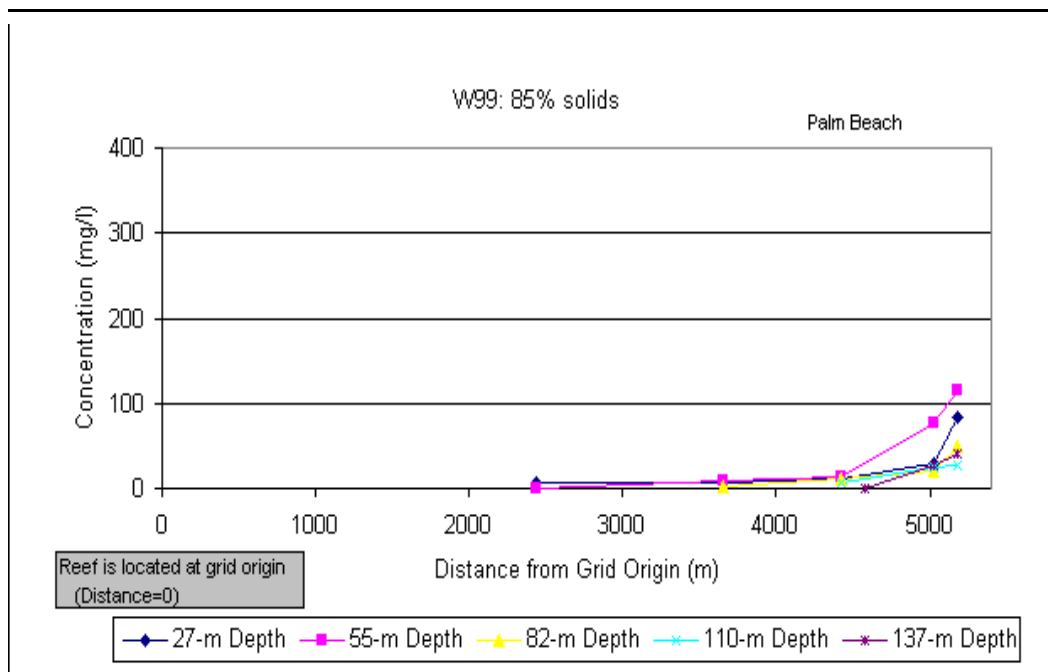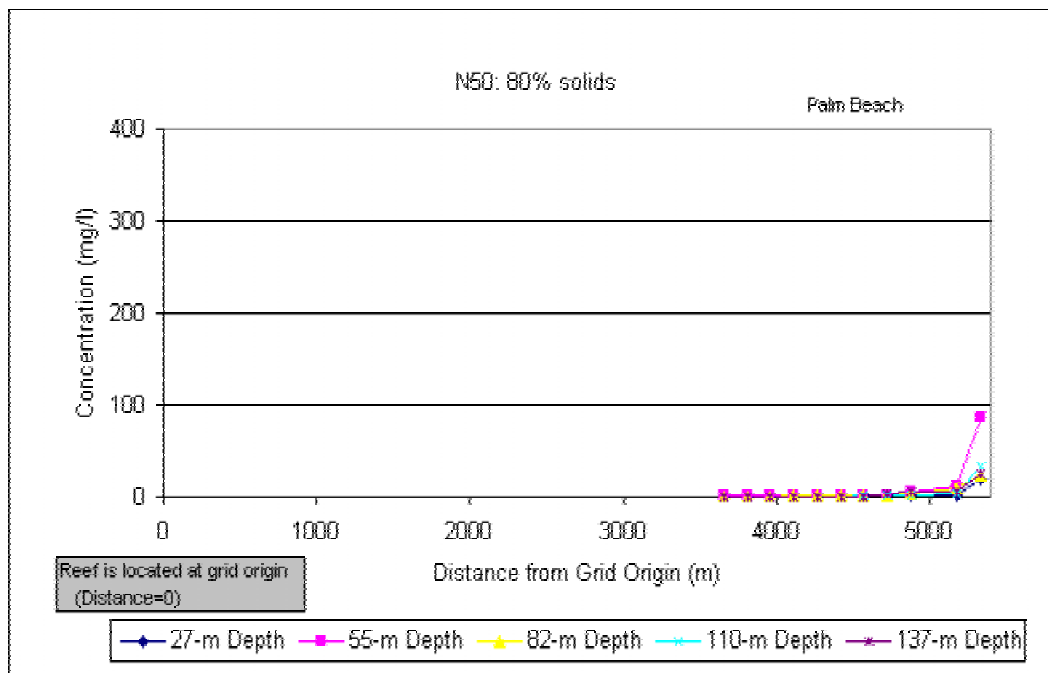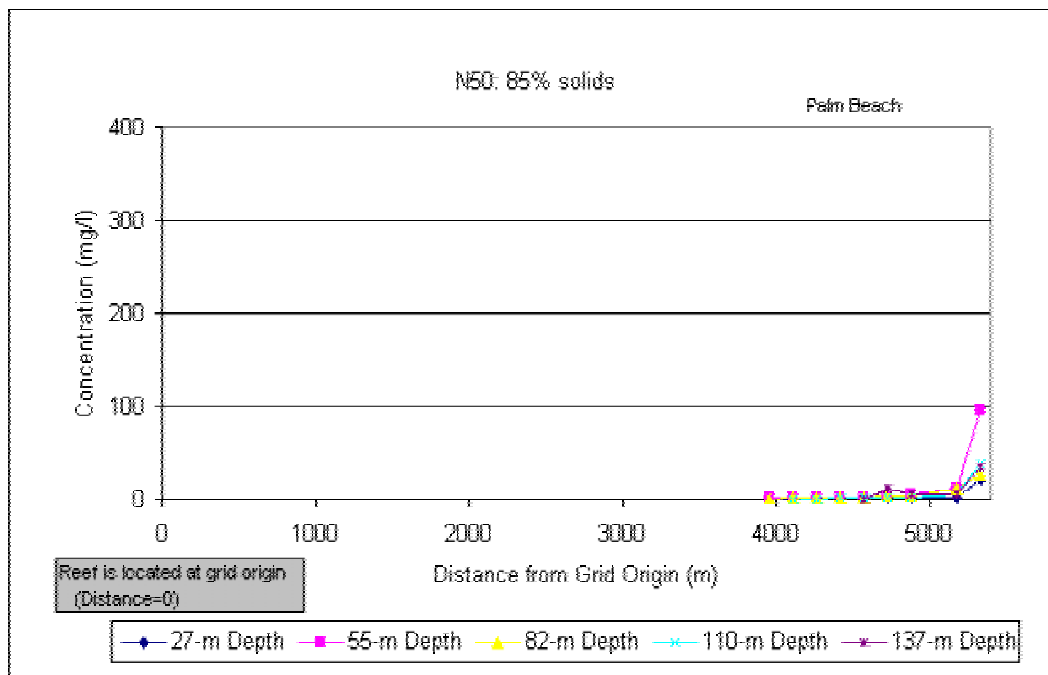Figure 33. Total sediment concentration
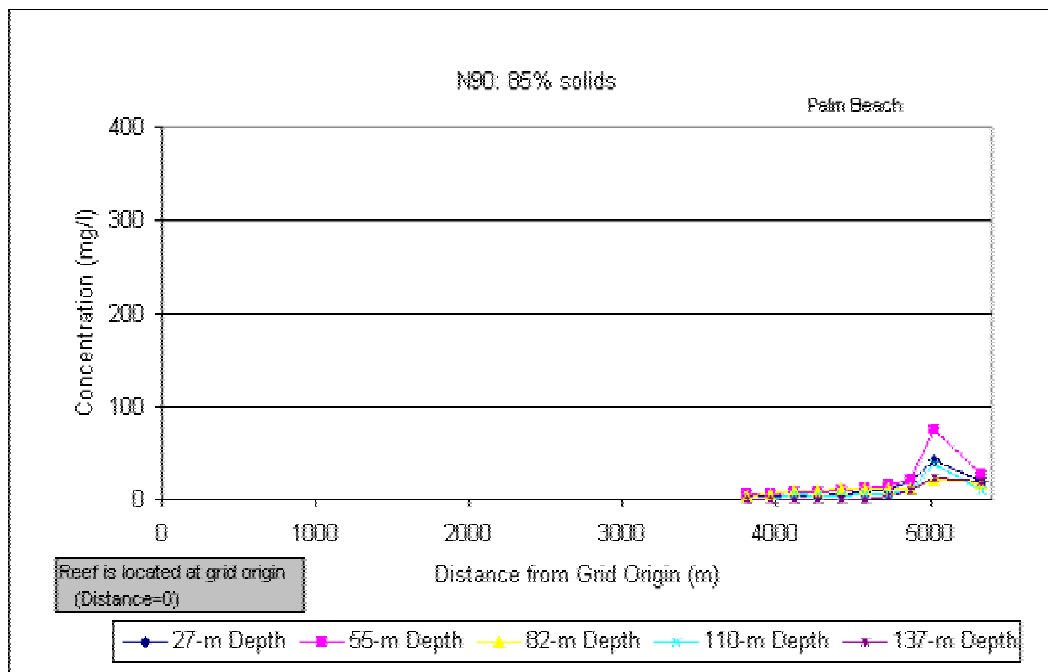
Figure 34. Total sediment concentration
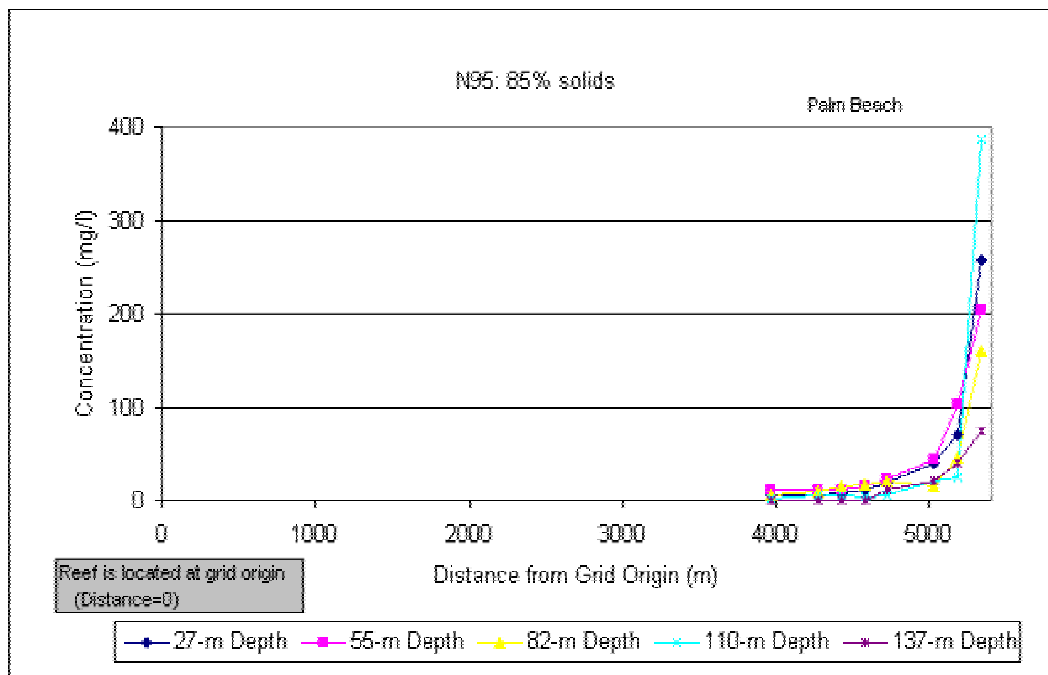
Figure 35. Total sediment concentration
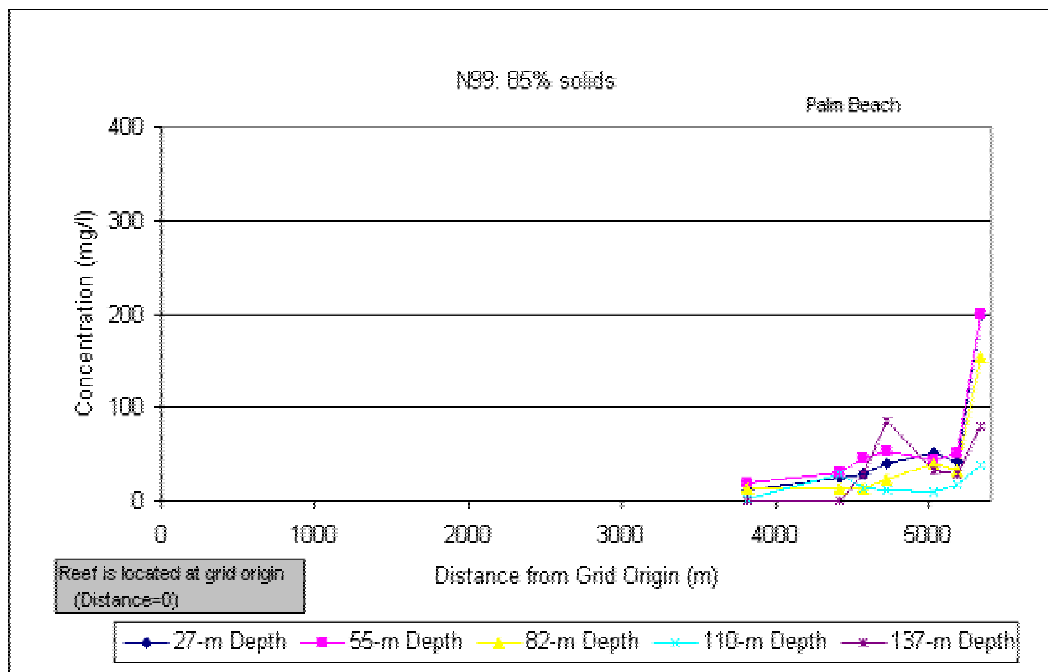
Figure 36. Total sediment concentration

Velocity Data for the Palm Beach Site

The ADCP data analyzed for the previous study represented the best-known source of long-term data at the time of the study. Figure 37 shows the location of the ADCP with respect to the Port Everglades and Palm Beach ODMDS sites. The Palm Beach site is about 70 km to the north of the ADCP, therefore a search for additional velocity data for Palm Beach was requested by SAJ to determine if current data closer to Palm Beach ODMDS has become available.

Numerous personal contacts were made and web sites were searched for velocity data in the Palm Beach area as shown in Tables 4 and 5. No data closer to the Palm Beach site than the previously used ADCP were found. Therefore, the Environmental Protection Agency (EPA) suggested writing a brief description of the Florida Current to justify the use of the ADCP data for the Palm Beach ODMDS. It was then requested by SAJ that a brief description of the Florida Current be prepared.

Florida Current

The origin of the Gulf Stream begins as the Atlantic and North Equatorial Current system combines with the South Equatorial and Guyana Current system. This combined flow discharges through the Caribbean Sea and Yucatan Channel into the southeastern portion of the Gulf of Mexico. Because the waters are colder than the surrounding Gulf of Mexico, a density differential is created which results in a deflection of the current from the Gulf of Mexico toward the Straights of Florida (EPA, 1995).

Figure 37. Location of the ODMDSs with respect to the ADCP

Table 4. Personal Contacts		
Name	Affiliation	Search Findings
Margaret Sabol	CHL	No data was found.
Jack Davis	CHL	No data was found.
Norman Scheffner	CHL	No data was found.
Robert Dean	University of Florida	They measured velocity data in very shallow water (4 m) offshore of Palm Beach. The Palm Beach ODMDS site is located in water depths of about 170 m which is further offshore. Also some data was collected during the late 1970's offshore of Ft. Lauderdale but the ADCP data, used in the study, collected more recent data (1995-1997) offshore of Ft. Lauderdale.
Don Slinn	Florida Atlantic University	They deployed an ADCP approximately 12 miles offshore of Ft. Lauderdale. The position of the ADCP used in the previous study is about 3 miles offshore of Ft. Lauderdale which is closer to the study area. Also, the data cannot be made public for approximately another year.
Ryan Smith Doug Wilson	NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML)	No reply.
E-mail contact	Oceanographer of the Navy	No reply.
Bill Venezia	South Florida Ocean Measurement Center	They do not have velocity data off Palm Beach and they are interested in such data. They are collecting real time velocity data from an ADCP southeast of Port Everglades in 520 ft water depth. This is the same location from which ADCP data used in the original study were acquired (26 degrees 4' N by 80 degrees 3.5' W).

Table 5. Web Sites Table	
Web Site	Search Findings
Center of Operational Oceanographic Products & Services (NOAA)	No data was found.
South Florida Information Access Database (USGS)	No data was found.
Naval Surface Warfare Center (NAVY)	No data was found.
Ocean Planet: Ocean Currents (NASA)	No data was found.
Interactive Marine Observations (FSU)	No data was found.
National Oceanographic Data Center (NODC)	The only data collected by NODC close to Palm Beach was the data used in the original study.

The movement of the Gulf Stream through the continental shelf often creates rotational patterns which propagate away from the main body of the Stream. These patterns generally represent unstable meanders which become detached from the main body of the Stream. These detached secondary currents are referred to as spin-off eddies. Richardson (1985) identifies three distinct zones of the Gulf Stream. These are the clockwise rotating onshore eddy, the axis or main body of the Stream, and the counterclockwise rotating offshore eddy. The high velocity axis of the Gulf Stream acts as a barrier separating the onshore and offshore regions. Depending on the environmental conditions, detached onshore eddies can propagate to the north, shoreward, or to the south with short-lived periods ranging from 2 days to 2 weeks. The meandering process is well illustrated in an example presented by Bane and Brooks (1979). In Figure 38, a 64-week period of Sea Surface Temperature data is used to show the shoreward and seaward envelope of occupation of the Gulf Stream in relation to the location of the time-averaged mean axis shown by the dashed line.

The Florida Current is that portion of the Gulf Stream system that connects the loop Current in the Gulf of Mexico to the Gulf Stream as it proceeds through the Straits of Florida and into the open Atlantic Ocean (Lee et al., 1977). Over most continental shelves, circulation is primarily governed by tides and winds. Off the southeast coast of Florida, circulation is also strongly influenced by the Florida Current.

The Florida Current influences coastal circulation on the southeast Florida Shelf in two ways, depending on the degree of intrusion of this current over the continental shelf (EPA, 1973). According to the EPA (1995), "When the western edge of the Florida

Current is over the shelf, the current draws the coastal waters north, though velocities may be considerably reduced due to bottom friction. When the western edge of the Florida Current is seaward of the continental shelf, cyclonic spin-off eddies are formed. These eddies, with an average diameter of 10-30 km, are usually carried north, but cyclonic currents inside the eddies may control local current patterns. Following their formation, spin-off eddies usually travel northward along the continental margin at speeds ranging from 20 to 50 cm/s. At these rates, it generally takes less than one day for an eddy to pass a fixed point (Lee et al., 1977). Eddies occur, on average, once per week and can be recognized as disruptions of prevailing temperature and salinity fields and of local current patterns (Lee and Mayer, 1977)." These cyclonic eddies play an important role in coastal exchange processes, removing coastal water and replacing it with waters from the Florida Current.

The western boundary of the Florida Current is distinguished from the inshore waters by a sharp rise in sea surface temperature. Movement of the western boundary near Fort Pierce was studied by Fornshell (2000) using satellite imagery for a period of 51 days from January 21, 1998 to March 13, 1998. At Fort Pierce, which is north of the study area, Fornshell found the average distance from shore to the western boundary of the Florida Current was 29.3 km. There were five incursions onto the continental shelf by the Florida Current during the study with an average recurrence interval of 10 days. This is approximately the same periodicity as the spin-off eddies reported by Lee (1975) and Lee et al. (1977) based on measurements made south of the study area. During the 51-day period, the average distance from shore to the western boundary of the Florida current was 8 to 60 km. Figure 39 shows the observed positions of the Florida Current during the 51 days of the study. At this location near Fort Pierce, the distance from the shoreline to the shelf break is about 40 km.

Figure 40 shows the bottom topography in the study region. Locations where Fornshell (2000), Lee (1975), and Lee and Mayer (1977) examined the Florida Current, the Palm Beach and Port Everglades ODMDSs, and the location where the ADCP data used in this study were acquired, are also shown. The mean axis of the Gulf Stream (see Figure 38) and the shelf break (Figure 40) are nearly parallel in the study region. As seen in Figure 38, the meander deviation decreases with increasing proximity to the study area. The width of the shelf and the distance from shoreline to shelf break also decreases with increasing proximity to the study area. The shelf break plays a dominant role in steering the Florida Current. It is important to note the similarity in both shelf topography, and the distance from shore to the shelf break at the Palm Beach and Port Everglades ODMDs and at the location where the ADCP data were acquired. The ODMDS sites and the ADCP site are located about 3 km west of the shelf break, i.e., about 7 km from the average position of the western boundary of the Florida Current. North of Palm Beach and south of Port Everglades, the topography varies (shelf widens and distance from shore to shelf break increases), but at these three locations and in the region between them, the topography is quite similar. With the dominant current flowing to the north, steered by the shelf break, and with a mean Gulf Stream position that is located a similar distance from shore at both Palm Beach and Port Everglades (see Figure 38), it is logical that the predominant current flowing along the shelf would be similar in magnitude at the two sites. In general, the currents might be slightly less at Palm Beach, since the shelf begins to widen at this location, and continues to widen with increasing distance north of the site.

The EPA has expressed concern regarding the fate of the dredged material disposed at the ODMDSs due to their proximity to the Gulf Stream and its spin-off eddies. The average
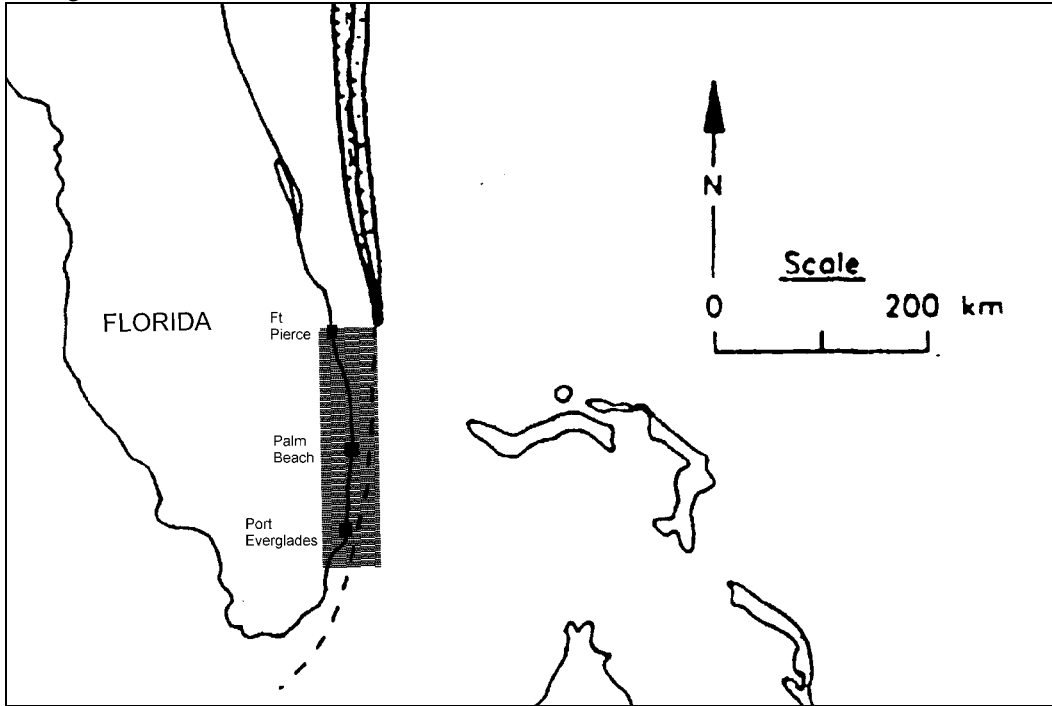
Figure 38. Mean position (dashed line) and meander deviation of the Gulf Stream surface (Bane and Brooks, 1979). The black box shows the study area
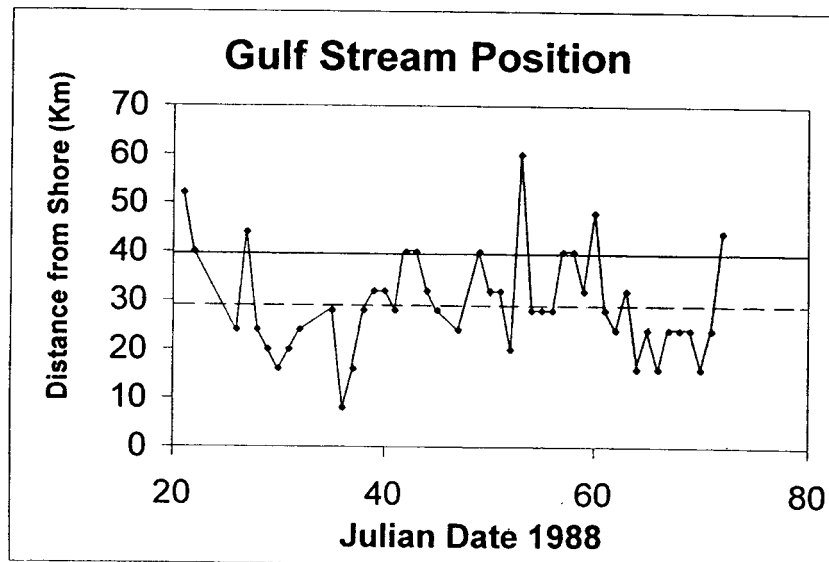
Figure 39. Observed positions of the Florida Current at Fort Pierce. The solid horizontal line represents the shelf break and the dashed line is the average position of the western boundary

25

of the Florida Current. (Fornshell, 2000)
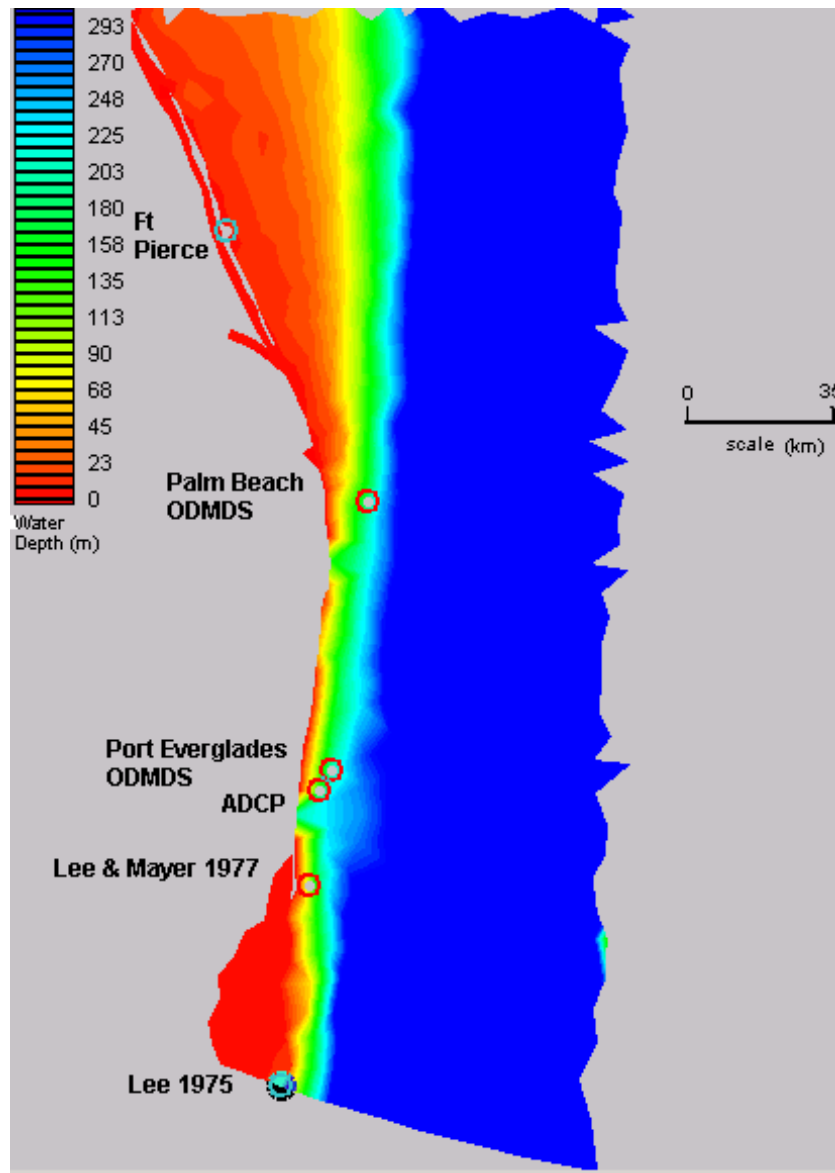
Figure 40. Topographic map for the study area

diameter of the spin-off eddies in this region is about 10 to 30 km. The small distance between shoreline and shelf break in the study region (about 10 km) probably constrains the formation and propagation of eddies, compared to areas where the shelf is much wider. However, the similarity in shelf topography at both ODMDS sites, and at the ADCP site, suggests that eddies are constrained in a similar way at all three sites. The ADCP and the ODMDS sites are expected to experience similar effects of the spin-off eddies. In light of the length scale of the eddies, similarity in shelf topography, and similar proximity to the western boundary of the Florida Current, currents at the three sites can be expected to be

similar. Therefore, it is justified to use the ADCP current data for the Palm Beach ODMDS.

STFATE Modeling of "Typical" Current Profile

The typical (V_{50}) velocity profile modeled using STFATE was derived from analysis of the 0-5 deg angle band described in Cialone and Lillycrop (1998). Simulating sediment transport under these conditions will provide a description of phenomena under typical conditions. Figure 41 shows the typical velocity profile to be modeled using STFATE. In the previous study, STFATE modeling involved either a varying bathymetry or a varying velocity profile. Available model technology did not incorporate variation in both depth and velocity. Therefore, to complete this task, model modifications to adopt a four-point velocity profile were made. Also, a MATLAB routine was used to read the STFATE concentration output file and spatially add the sand and silt-clay concentrations to estimate the maximum total concentration within the grid.
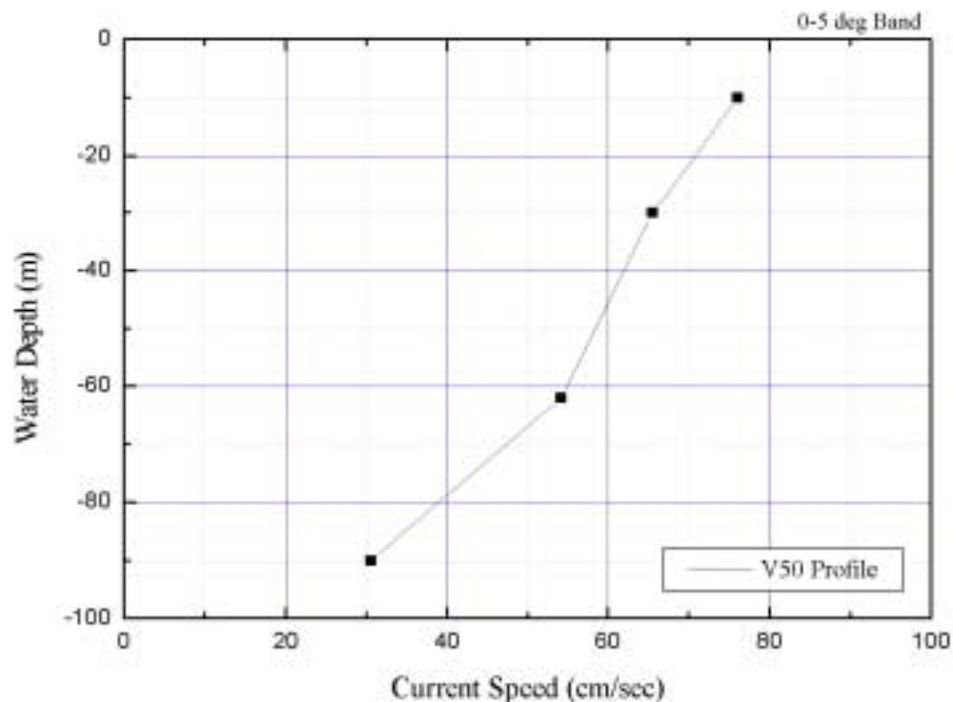

Figure 41. Typical velocity profile

Port Everglades

The input files of the original model simulations were not retrievable. Where possible, the input parameters were extracted from the available original output files. Most of the input parameters were retrievable and the rest were assumed.

Before running the STFATE model for the typical profile, STFATE was run for a northwesterly-directed velocity of 1% exceedance and 60% solids (N99: 60%) case with a one point (constant of 200 cm/s) velocity profile. The goal of the STFATE run was to verify that the retrieved and assumed input data could reproduce the same output as the original simulation. Figures 42-44 show the comparison of the old and new output data for sand and silt-clay sediment concentrations. The results showed a consistent pattern and very good agreement in values for some cases. Inconsistency in the results can be attributed to the assumed values in the input file.

The concentrations of sediment subjected to a typical velocity profile were obtained by running the modified version of the STFATE model. Figures 45-47 show the comparison between the results for the typical 4-point velocity profile input and the one-point velocity input. It can be seen from the results that the general pattern is conserved and close agreement is seen for the sand case. For the silt-clay sediment, the general pattern is similar for the typical 4-point velocity profile input and the one-point velocity input.
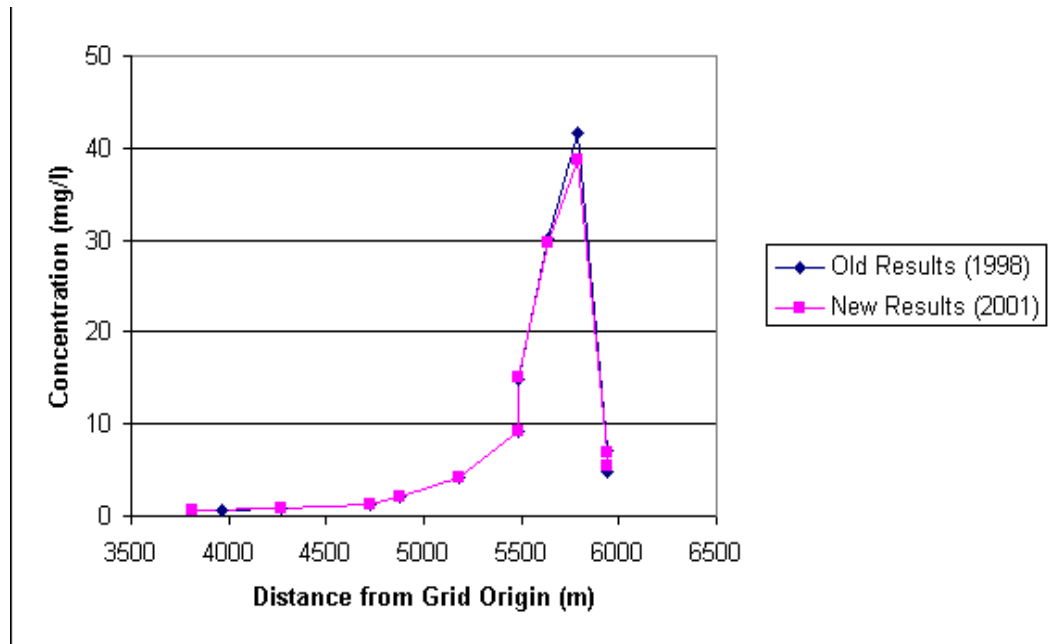
Figure 42. Comparison between old and new output data for sand at 46-m depth
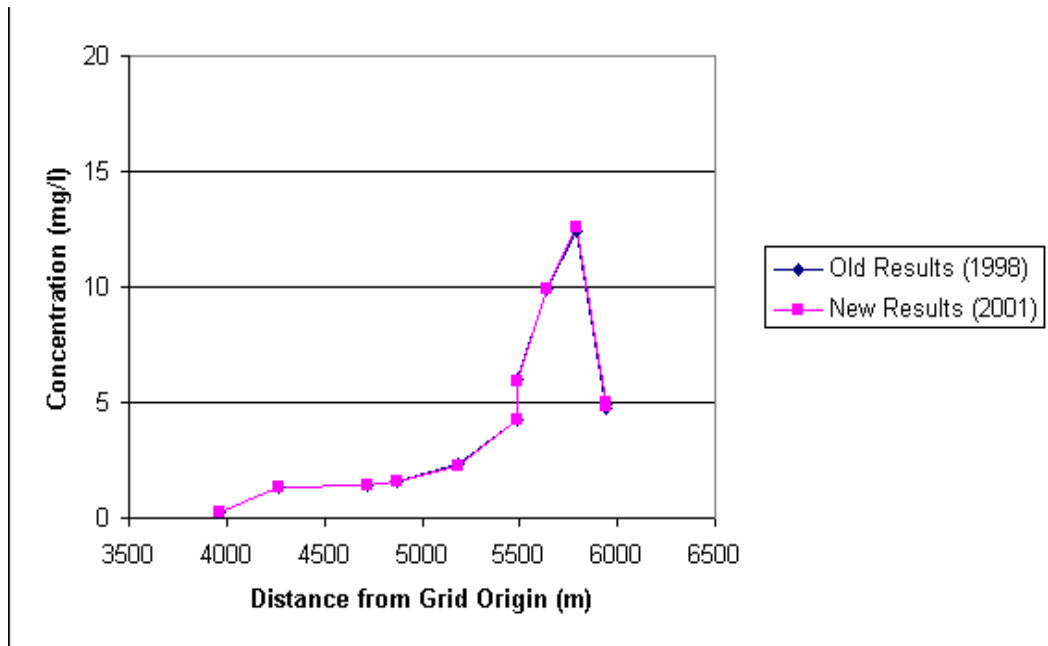
Figure 43. Comparison between old and new output data for sand at 168-m depth
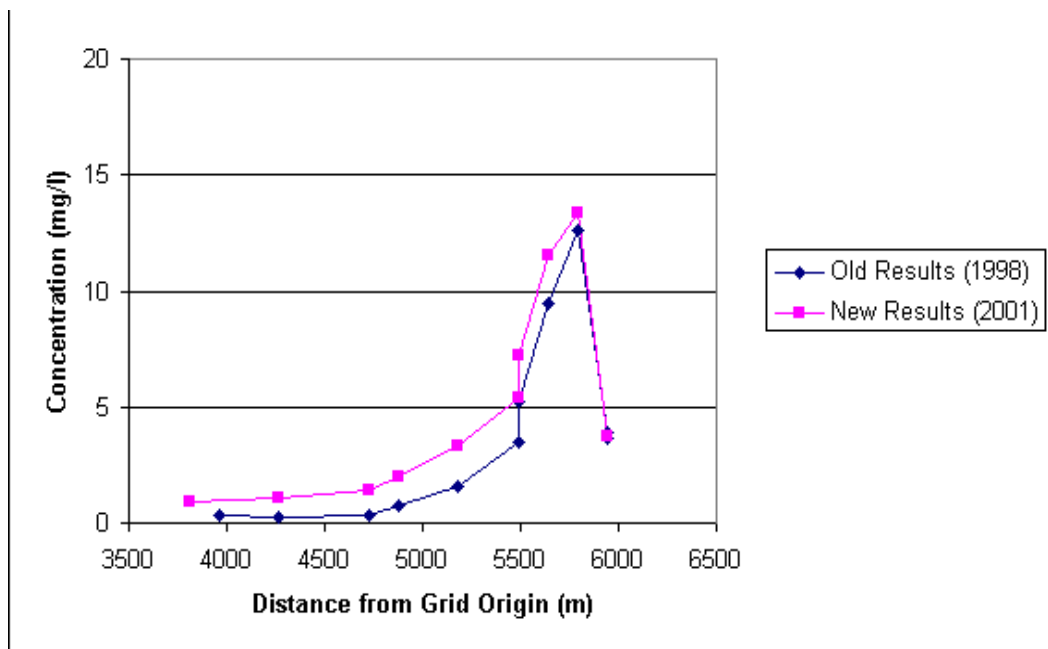

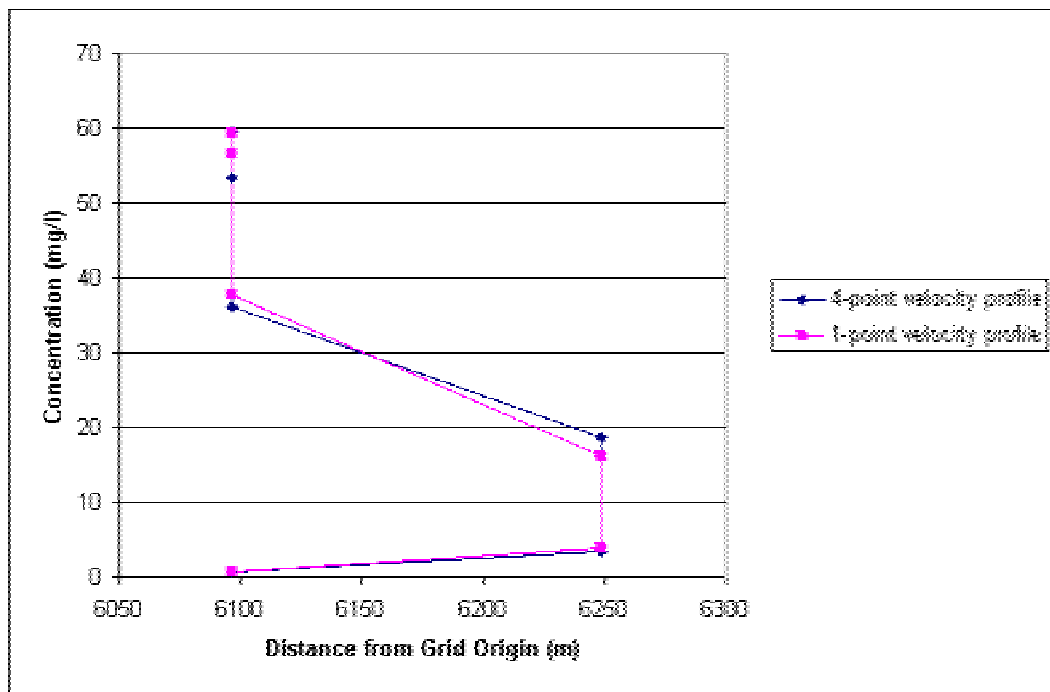Figure 44. Comparison between old and new output data for silt-clay at 107-m depth

Figure 45. Comparison between STFATE results for typical 4-point velocity profile input and the one-point velocity input for sand at 46-m depth
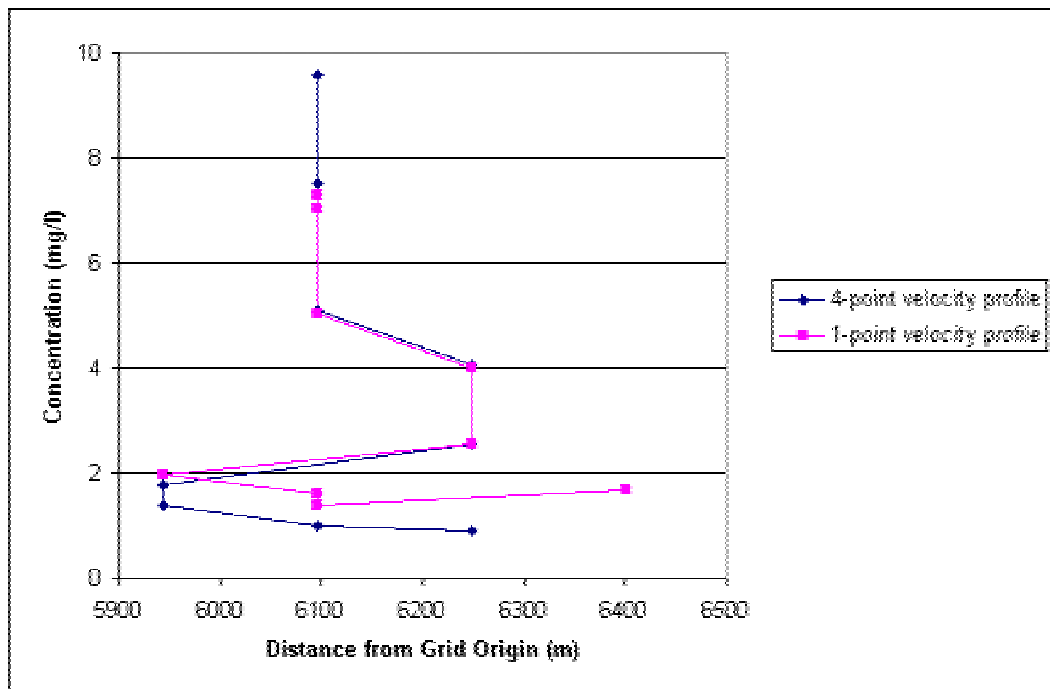
Figure 46. Comparison between STFATE results for typical 4-point velocity profile input and the one-point velocity input for sand at 168-m depth
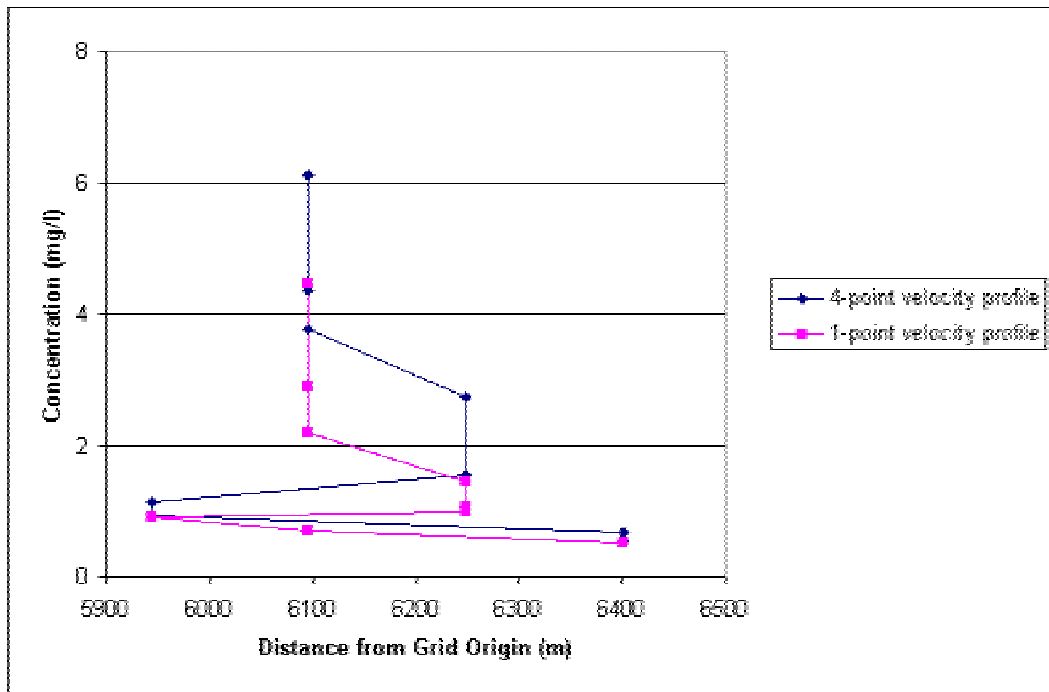
Figure 47. Comparison between STFATE results for typical 4-point velocity profile input and the one-point velocity input for silt-clay at 107-m depth

The flow direction associated with the typical profile is approximately to the north and the sediment was disposed 6100 m from the grid origin (reef location). The total concentration results for the 60% solids and 70% solids are shown in Figures 48 and 49 respectively. The bubble size is proportional to the total concentration value. Concentration values are also listed. The maximum concentration in the water column after 1200 sec was 74.6 mg/l for the 60% solids case and 91.5 mg/l for the 70% solids case. After 6000 sec, the maximum total concentration in the water column recorded for the 70% solids case was 2 mg/l and at a distance of 6250 m from the reef.

Results from the previous study show that the maximum total concentration in the water column recorded for the N50: 70% case was 0.85 mg/l and was 2.03 mg/l for the W50: 70% case at a distance of 5000 m from the reef in both cases. The distance of 5000 m from the reef was the minimum distance for which the maximum total sediment could be calculated for both the W50: 70% case and the N50: 70% cases. When the direction of the velocity was toward the west a higher value of concentration was recorded at a distance of 5000 m from the reef than when the velocity was directed toward the northwest.

60% Solids
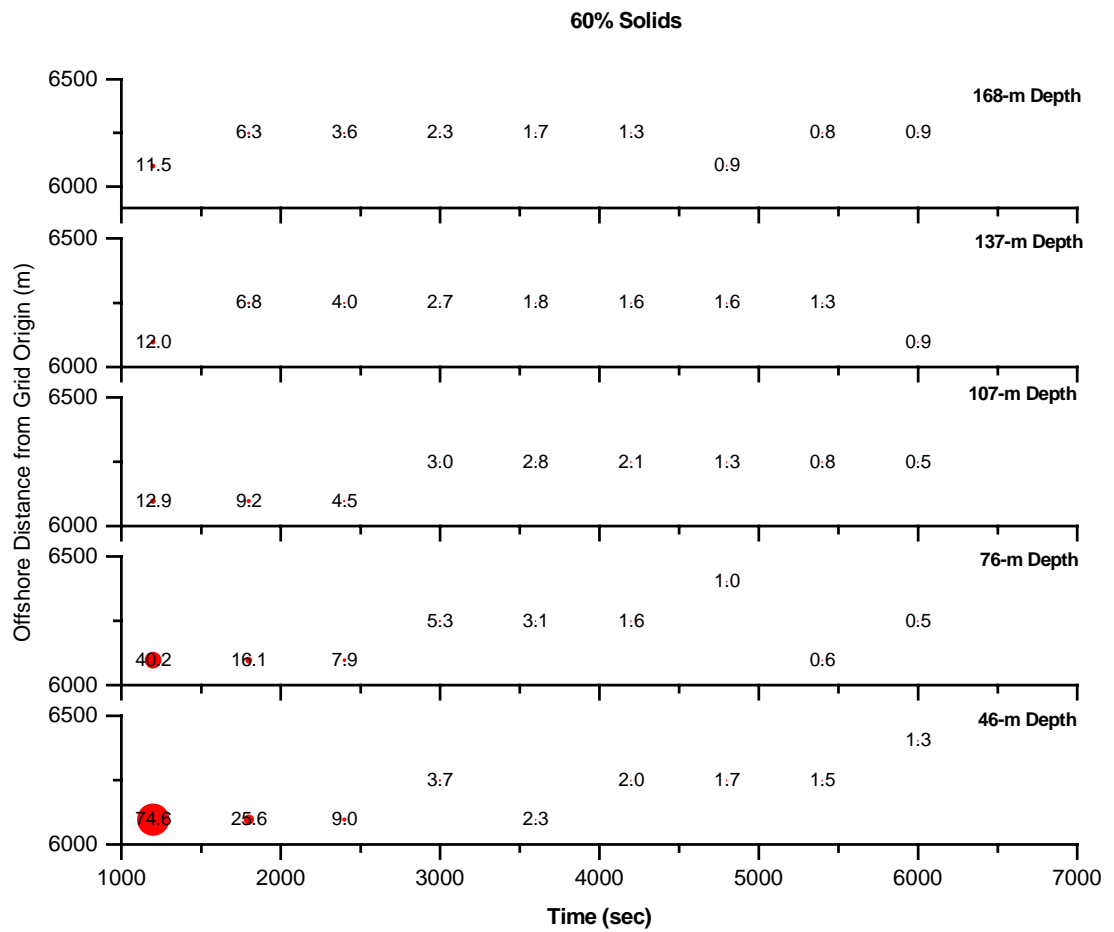
Figure 48. Total sediment concentration in mg/l at Port Everglades (depths are measured from the water surface)
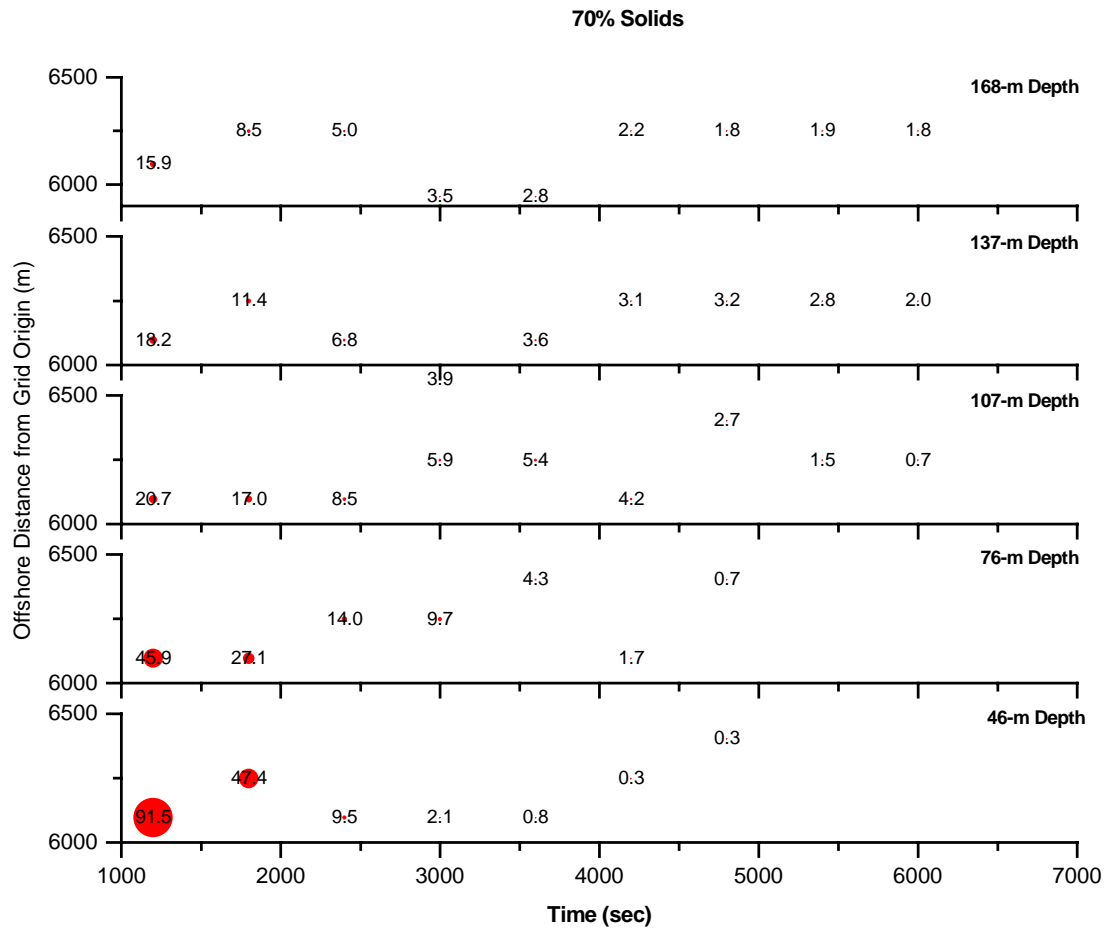
Figure 49. Total sediment concentration in mg/l at Port Everglades
(depths are measured from the water surface)

However, in the case of the typical velocity profile the sediment was moving toward the northeast and not toward the reef. Concentrations were never observed west of the disposal location, which was 6100 m from the reef. The results show that sediment is moving toward the north and approximately parallel to the shore away from the reef for the typical velocity profile. The direction of the velocity is a main factor in directing the sediments toward or away from the reef. Therefore it can be concluded that there is no potential for sediment movement from the ODMDS at Port Everglades onto the reef.

Palm Beach

The input and output files from the original model simulations were not completely retrievable. Therefore some input parameters were recreated and others were assumed. The depth input matrix was not available and was recreated from NOAA Chart 11466. Another main input assumption was the alongshore position of the sediment disposal.

33

Before running the STFATE model for the typical profile, STFATE was run for a northwesterly-directed velocity of 1% exceedance and 80% solids (N99: 80%) case. As for Port Everglades, the goal of the STFATE run was to verify that the retrieved and assumed input data could reproduce the same output as the original one. Figures 50-52 show the comparison of the old and new output data for sand and silt-clay sediments. The results showed similarity in the general pattern of the concentration profiles. The comparison of the old and new results for Port Everglades showed better agreement than those for Palm Beach because more input data were assumed for the Palm Beach case.
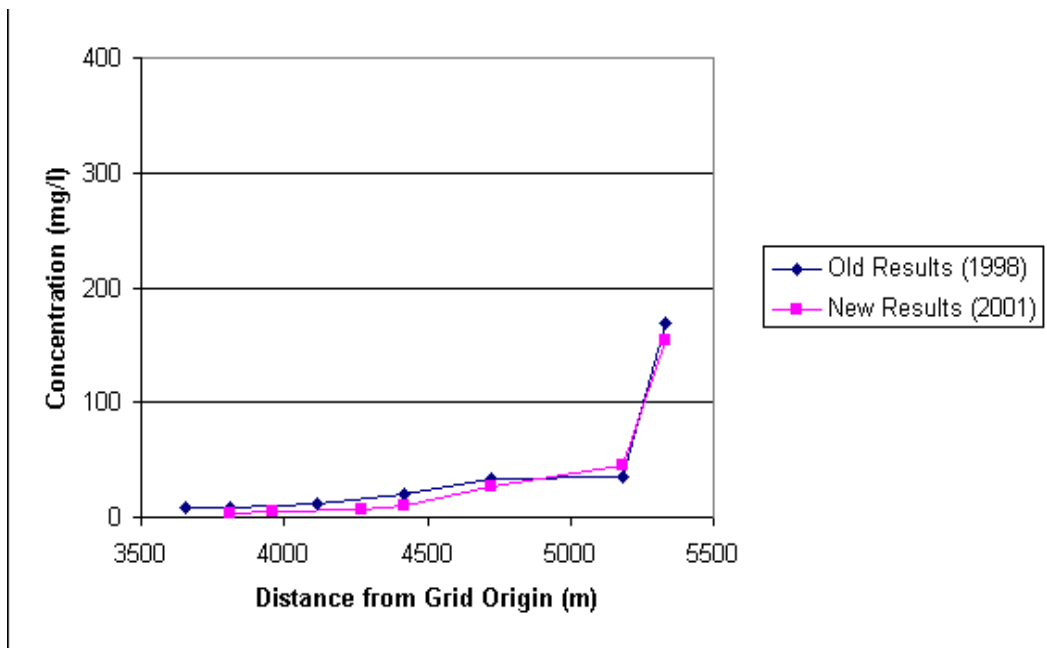
Figure 50. Comparison between old and new output data for sand at 27-m depth

The direction of the typical velocity profile is approximately to the north and the sediment was disposed 5500 m from the grid origin. The results for the 80% solids and 85% solids cases are shown in Figures 53 and 54 respectively. The bubble size is proportional to the total concentration value. The maximum concentration over the depth after 1400 sec was 91.9 mg/l for the 80% solids case and 124.4 mg/l for the 85% solids case. The maximum concentration over the depth recorded after 6300 sec and at a distance of 5800 m from the reef was 2 mg/l for the 85% solids case.
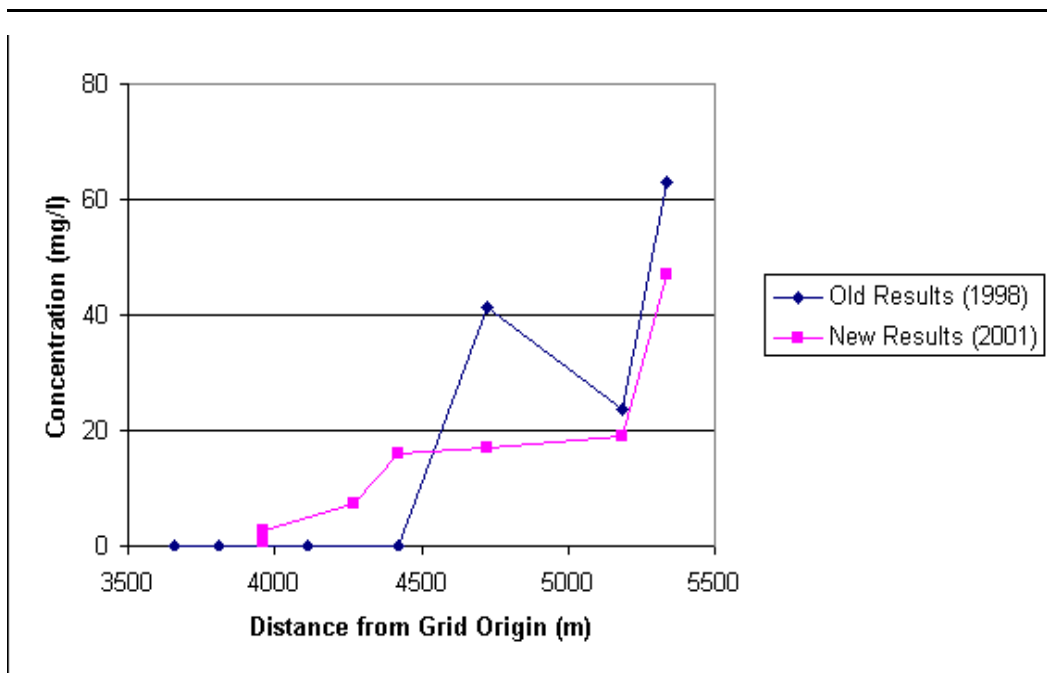
Figure 51. Comparison between old and new output data for sand at 137-m depth
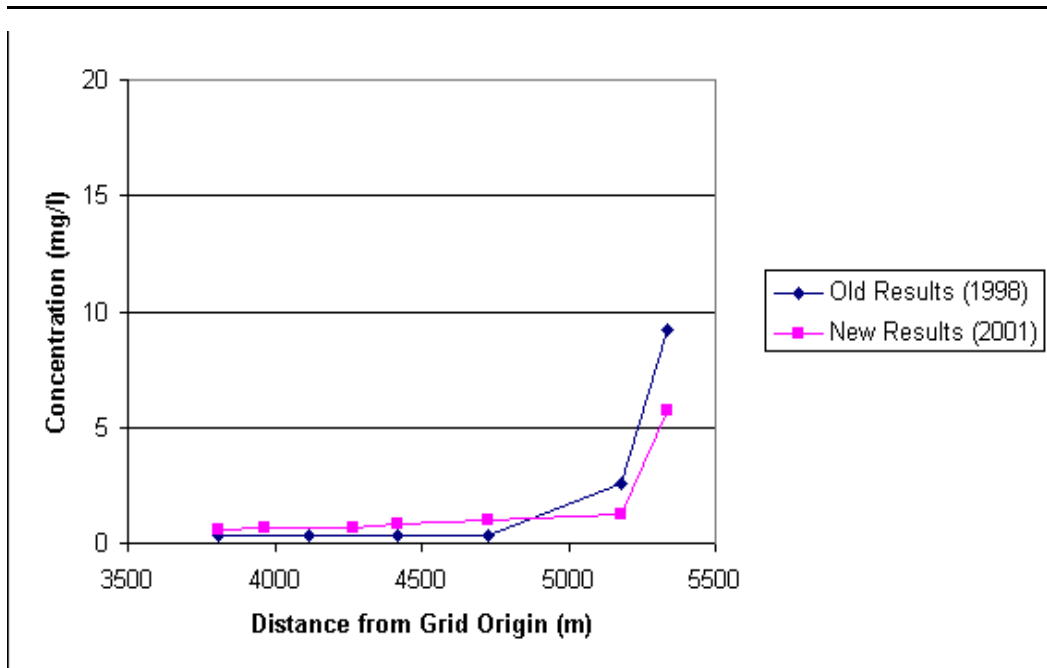
Figure 52. Comparison between old and new output data for silt-clay at 82-m depth

Results from the previous study show that the maximum concentration over the depth for the N50: 85% case at a distance of 4300 m from the reef was 1.69 mg/l and was 2.36 mg/l for the W50: 85% case. The distance of 4300 m from the reef was the minimum

distance for which the maximum total sediment could be calculated for both the W50: 85% and the N50: 85% cases. When the direction of the velocity was toward the west a higher value of concentration was recorded at a distance of 4300 m from the reef than when the velocity was directed toward the northwest. In the case of the typical velocity profile the sediment was moving toward the north and the northeast. Concentrations of 0.3 mg/l and of 0.4 mg/l were recorded 300 m to the west of the 5500 disposal location for the 80% solids case the 85% case respectively. In general the sediment was moving toward the north away from the reef.

The results show that the sediment is moving toward the north and approximately parallel to the shore away from the reef. Therefore it can be concluded that there is no potential for sediment movement from the ODMDS at Palm Beach onto the reef.
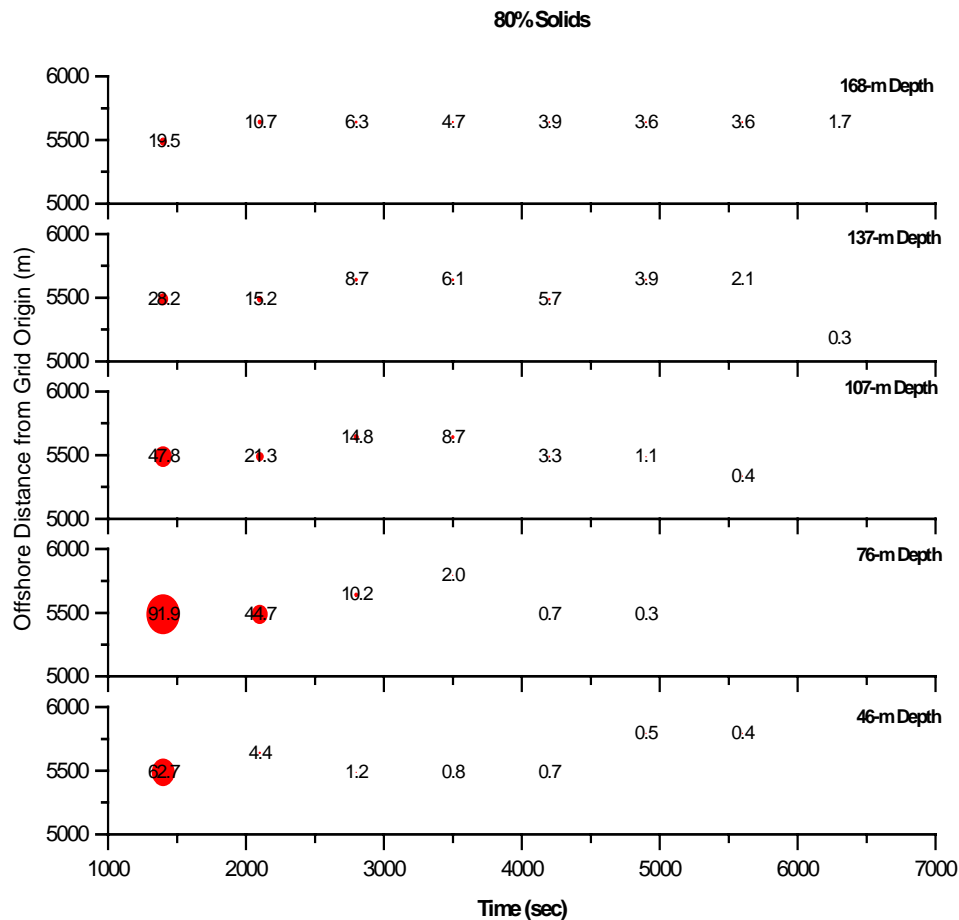
Figure 53. Total sediment concentration in mg/l at Palm Beach (depths are measured from the water surface)
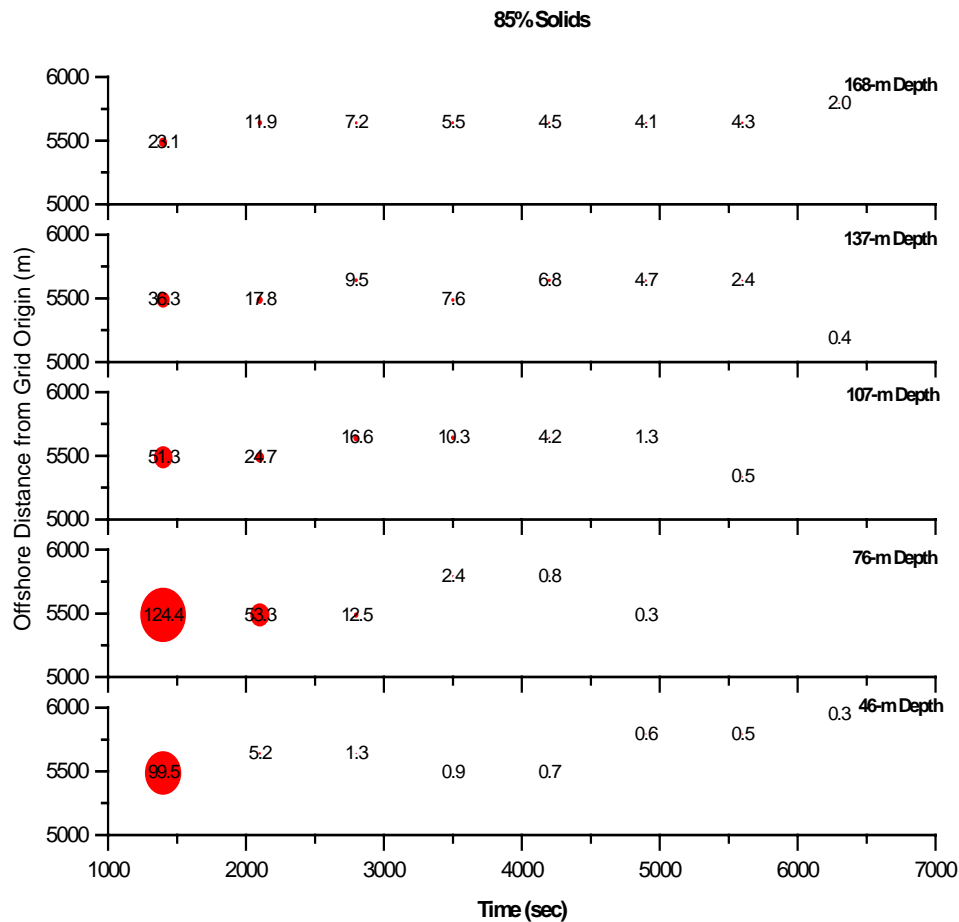
Figure 54. Total sediment concentration in mg/l at Palm Beach
(depths are measured from the water surface)

Screening Level Model Application

In the original work a screening level erosion model was used to estimate the long-term response of the dredged material mounds at the Port Everglades and Palm Beach ODMDSs to local environmental forcing functions. In the previous study the screening level erosion modeling was completed for the three largest historical storms selected from the National Hurricane Center's HURDAT database. An additional case of a severe extratropical storm was simulated for the Port Everglades site. The model was used to estimate the peak sediment flux and total sediment loss caused by the three severe tropical storms. A 305 m × 305 m × .41 m square mound configuration was assumed for a 50,000 c. y mound. This volume represents the annual amount that each disposal site is expected to accommodate. The total sediment loss for each storm, in which the peak flux was assumed to occur for four hours across one side of the 305 m × 305 m disposal site, are shown in Table 6.

SAJ suggested applying the screening level erosion model for a larger mound of 500,000 c. y (ten times the volume). to simulate the long-term fate of the disposal mound for both sites. The assumed dimension of the proposed mound was 965 m × 965 m × .41 m. The depth of the assumed mound was kept the same as what was assumed in the previous study. It is a normal tendency of the disposal mounds to be spread horizontally and maintain a depth of less than 1 m. The input data to the screening level model (wave height, wave period, water depth, sediment size, and velocity) were those used in the previous application. The total sediment loss for each storm, in which the peak flux was assumed to occur for four hours across one side of the 965 m × 965 m disposal site, are shown in Table 6.

It can be seen from Table 6 that when the mound size is increased 10 times the new total sediment loss for each storm increased about 3 times. The loss per unit width of the mound is a function of the mound elevation, which was the same as the original study. The total volume loss corresponds to the increased width of the mound. The maximum computed total sediment loss is 11 m^3, which is associated with the tropical storm 353 at Port Everglades, and is less than .003% of the disposed mound volume of 500,000 c. y. Therefore, even during the most severe storms and with mounds ten times larger than the annual amount that each disposal site is expected to accommodate, the mounds at Port Everglades and Palm Beach will not be significantly eroded.

Table 6. Total volume (m^3) eroded from Port Everglades and Palm Beach mounds							
	Port Everglades				**Palm Beach**		
	Storm 276	Storm 292	Storm 353	Severe Extra-tropical Storm	Storm 276	Storm 292	Storm 353
Present Study	0	0	11	4	0	0	10
Previous Study	0	0	3.5	1.3	0	0	3

Summary and Conclusions

STFATE was used to estimate the dynamics of the sediment cloud following its release from the dredge. The model computes the time-history of a single disposal operation from the time the dredged material is released from the barge until it reaches equilibrium.

In all Port Everglades applications sediment was disposed 6100 m from the grid

origin (reef location). Two sediment compositions were simulated, 60% and 70% solids by weight, with 38% and 5% fines, respectively. Results indicate silt-clay concentrations diminish to approximately 1 mg/l or less at a distance of 1500 m of the disposal location. Higher current speeds carry sediment from the disposal location more rapidly, but silt-clay concentrations still drop below about 1 mg/l within 1500 m of the disposal location. A major portion of the dredged material is sand. Sand concentrations diminish to 1 mg/l or less at a distance of 2440 m of the disposal location. Since the previous study was dealing with each portion of sediment alone, the above mentioned values correspond to different distances from the reef and different velocity input conditions.

The present results indicate that under the most severe conditions (N99: 70%), the maximum total sediment concentration within 4000 m from the reef location was approximately 3 mg/l at a depth of 137 m. A major portion of the dredged material is sand. The sand concentration was 2.7 mg/l while the silt-clay concentration was 0.5 mg/l.

In all Palm Beach applications sediment was disposed 5500 m from the grid origin (reef location). Two sediment compositions were simulated, 80% and 85% solids by weight, with 6% fines. Silt-clay concentrations diminish rapidly to 1 mg/l or less within 1500 m of the disposal location. Higher current speeds carry sediment from the disposal location more rapidly, but silt-clay concentrations still drop below 1 mg/l within 1500 m of the disposal location. A major portion of the dredged material is sand. Sand concentrations diminish to 1 mg/l or less within 2400 m of the disposal location.

The present results indicate that under the most severe conditions (N99: 85%), the maximum total sediment concentration within 3800 m from reef location was approximately 19 mg/l at a depth of 55 m. A major portion of the dredged material is sand with a concentration of 17.4 mg/l, while the silt-clay concentration value was 1.5 mg/l. The sand in the dredged material settles rapidly and it is expected that the concentration will decrease with closer distance to the reef.

The EPA has expressed concern regarding the fate of the dredged material disposed at the ODMDSs due to their proximity to the Gulf Stream and its spin-off eddies. The current data used in the previous study was obtained from an ADCP positioned about 70 km to the south of the Palm Beach ODMDS site and in close proximity to the Port Everglades site. It was not possible to obtain additional velocity data near Palm Beach. Therefore, a brief description of the Florida Current was prepared to evaluate the use of ADCP velocities for the Palm Beach ODMDS. Ocean currents in the vicinity of the sites are generally along the north-south axis steered by shelf break. The shelf topography and distance from shoreline to the shelf break at both ODMDS sites and the ADCP location are quite similar. At times, the Florida Current does generate, or contribute to, shoreward directed velocity fields which may affect the disposal sites. The ODMDS sites and the ADCP are located about 3 km from the shelf break, i.e., about 7 km from the average position of the western boundary of the Florida Current. Since the average size of the spin-off eddies is about 10- 30 km, then the ADCP and the ODMDS sites are expected to experience similar effects of the spin-off eddies. Because of the proximities of both ODMDSs and the ADCP to the shelf break and the Florida Current and its spin-off eddies and because of similarities in shelf topographies and distances between shoreline and shelf break at the ODMDSs and ADCP sites, currents at the three sites can be expected to be similar. Therefore, it is justified to use the ADCP current data for the Palm Beach

ODMDS. The current data used to evaluate the dispersion and movement of sediments at the ODMDSs is obtained from the ADCP which includes data associated with spin-off eddies that might lead to transporting sediment toward the shore. Therefore, the model results which indicate the movement of the sediment did include the effects of the spin-off eddies.

The typical velocity profile, modeled using STFATE, provides a description of phenomena under typical conditions. In the previous study, STFATE modeling involved either a varying bathymetry or a varying velocity profile. Available model technology did not incorporate variation in both depth and velocity. Model modifications to adopt a four-point velocity profile were made in this study.

Sediment was disposed 6100 m from the grid origin (reef location) at Port Everglades. The maximum concentration in the water column after 1200 sec was 74.6 mg/l for the 60% solids case. The maximum concentration after 1200 sec was 91.5 mg/l for the 70% solids case. The maximum total concentration recorded for the 70% solids case was 2 mg/l after 6000 sec, at a distance of 6250 m from the reef. The maximum total concentration over the depth recorded from the previous study for the N50: 70% case at a distance of 5000 m from the reef was 0.85 mg/l and was 2.03 mg/l for the W50: 70% case. The distance of 5000 m from the reef was the minimum distance for which the maximum total sediment could be calculated for both the W50: 70% case and the N50: 70% case. It can be concluded that when the direction of the velocity was toward the west a higher value of concentration was recorded at a distance of 5000 m from the reef than when the velocity was directed toward the northwest. However, in the case of the typical velocity profile concentrations were never observed west of the disposal location and the sediment was moving toward the northeast and not toward the reef.

The sediment was disposed 5500 m from the grid origin (reef location) at Palm Beach. The maximum concentration in the water column after 1400 sec was 91.9 mg/l for the 80% solids case and 124.4 mg/l for the 85% solids case. The maximum concentration after 6300 sec was 2 mg/l for the 85% solids case, at a distance of 5800 m from the reef. The maximum concentration recorded from the previous study for the N50: 85% case at a distance of 4300 m from the reef was 1.69 mg/l and was 2.36 mg/l for the W50: 85% case. The distance of 4300 m from the reef was the minimum distance for which the maximum total sediment could be calculated for both the W50: 80% case and the N50: 85% case. It can be concluded that when the direction of the velocity was toward the west a higher value of concentration was recorded at a distance of 4300 m from the reef than when the velocity was directed toward the northwest. In the case of the typical velocity profile, some concentrations associated with the disposal were recorded 200 m to the west of the disposal location but the sediment was generally moving toward the north and not toward the reef.

The direction of the velocity is a main factor in directing the sediments toward or away from the reef. Even for extreme velocities directed to the west and northwest, concentrations decrease substantially with distance away from the disposal location. In general the sediment is moving toward the north and approximately parallel to the shore away from the reef in both sites. Therefore it can be concluded that there is no potential for sediment movement from the ODMDSs at Port Everglades and Palm Beach onto the reefs.

The screening level model simulates the dispersive characteristics of a dredged material mound over time. The screening level erosion modeling was completed for three largest historical storms selected from the National Hurricane Center's HURDAT database. An additional case of a severe extra tropical storm was simulated for the Port Everglades site. A 965 m $\times$ 965 m $\times$ .41 m square mound configuration was assumed, associated with a 500,000 c. y of dredged material that represents 10 times the annual amount that each disposal site is expected to accommodate. The maximum computed total sediment loss of 11 m^3, which is associated with the tropical storm 353 at Port Everglades, is less than .003% of the disposed mound volume of 500,000 c. y. In the previous study, the maximum computed total sediment loss of 3.5 m^3, which is associated with the tropical storm 353 at Port Everglades, is also less than .003% of the disposed mound volume of 50,000 c. y (a negligible quantity). Therefore, even during the most severe storms and with mounds ten times larger than the annual amount that each disposal site is expected to accommodate, the mounds at Port Everglades and Palm Beach will not be significantly eroded.

References

Bane, J. M. and Brooks, D. A. 1979."Gulf Stream Meanders Along the Continental Margin from the Florida Straight to Cape Hatteras," Geophysics Research Letters, No. 6, pp. 280-282.

EPA, 1973. "Ocean Outfalls and Other Methods of Treated Wastewater Disposal in Southeast Florida," Final Environmental Impact Statement, U. S. Environmental Protection Agency, Region 4, Atlanta, Georgia.

EPA, 1995. "Final Environmental Impact Statement for Designation of an Ocean dredged Material Disposal Site Located off Miami, Florida," U. S. Environmental Protection Agency, Region 4, Atlanta, Georgia.

Fornshell, J. A. 2000. "Variability of Florida Current Offshore From Fort Pierce Florida as Revealed by Satellite Imagery," Marine Technology Society Journal, Vol. 34, No. 2.

Lee, T. N., Brooks, I., and Duing, W. 1977. "The Florida Current: Its Structure and Variability," Technical Report UM-RSMAS, No. 77003, The University of Miami, Rosesnstiel School of Marine and Atmospheric Sciences, Miami, Florida.

Lee, T. N., and Mayer, D. A. 1977. "Low Frequency Current Variability and Spin-Off Eddies along the Shelf off Southeast Florida," Journal of Marine Research, Vol. 35, No. 1, pp 193-220.

Richardson, P. L. 1985. "Average Velocity and Transfer of the Gulf Stream Near 55W," Journal of Marine Research, Vol. 43, pp 83-111.

Scheffner, N. W., and Swain, A. 1989. Evaluation of the dispersion characteristics of the Miami and Fort Pierce dredged material disposal sites. CoastalEngineering Research Center, Final Report to U. S. Army Engineer District, Jacksonville.